Air Quality Analysis of the Proposed Engineering Refinement to the Kuparuk River Unit Facilities

March 26, 1984

Submitted to:

Alaska Department of Environmental Conservation and U.S. Environmental Protection Agency Region X

Submitted by:

Kuparuk River Unit Owners

RADIAN CORPORATION

DCN 84-242-024-11-01

AIR QUALITY ANALYSIS OF THE PROPOSED ENGINEERING REFINEMENT TO THE KUPARUK RIVER UNIT

Submitted by:

Arco Alaska, Inc.

Submitted to:

State of Alaska

Department of Environmental Conservation

and

U.S. Environmental Protection Agency Region X

Prepared by:

Radian Corporation

March 1984

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EXECUTIVE SUMMARY

The Kuparuk River Unit Owners are proposing a modification to the source inventory for the Kuparuk River Unit (KRU) to reflect current engineering design refinements proposed for the KRU. The proposed KRU engineering design refinements indicate a need for 395 MM Btu/hr of heater capacity and 10 MHP of turbine capacity. This requirement for heater and turbine capacity will be balanced by deletions of previously permitted, but currently non-essential, heater and turbine capacity in the KRU.

The purpose of this document is to request an administrative change to the Prevention of Significant Deterioration (PSD) permit issued for the KRU to incorporate the proposed Engineering Refinement to the KRU. To support this request an air quality impact analysis was performed to assess any air quality impact changes resulting from the proposed Engineering Refinement. The maximum predicted impacts for nitrogen dioxide (NO_2), total suspended particulate matter (TSP), and sulfur dioxide (SO_2) decreased for all averaging times.

Emissions of total hydrocarbons (THC) and carbon monoxide (CO) will decrease for the Engineering Refinement to the KRU. Since previous analyses for the impacts of ozone (O_3) and CO were extremely conservative, previously predicted impacts of O_3 and CO remain valid and were not repeated.

The predicted air quality impacts due to the proposed Engineering Refinement to the KRU will not approach any National Ambient Air Quality Standard (NAAQS) or PSD increment.

1.0 INTRODUCTION

This request for an administrative change to the Kuparuk River Unit PSD permit application addresses impacts associated with design changes for the Kuparuk River Unit (KRU) facilities. The overall concept of the Kuparuk River Unit facilities is unchanged from that presented in the February 1983 permit application. The KRU facilties will still consist of drill sites, water injection facilities, power production facilities, a combined waste incinerator, and expansion of the existing Central Production Facility (CPF-1). Existing and previously licensed sources at CPF-1 will not change from the description in the original permit application.

Gas turbines and heaters still constitute the majority of the pollutant-emitting sources. A more detailed discussion of emissions sources, proposed emission controls, and air quality impacts of the engineering refinement to the Kuparuk River Unit is contained in the remainder of this report.

1.1 Applicant Information

This request for an administrative change to PSD Permit Number PSD-X82-01 is being submitted by ARCO Alaska, Inc. (a subsidiary of Atlantic Richfield Company), operator for the Kuparuk River Unit. Addresses and contacts are as follows:

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Location of Facilities

Kuparuk Oil Field
Kuparuk, Alaska

Approximate Center of Kuparuk Field:

Latitude: 70° 20′ N
Longitude: 149° 47′ W
UTM Coordinates: 401.0 km East, 7802.8 km North
UTM Zone: 6

1.2 Existing and Permitted Sources and Emissions

The inventory of existing and permitted sources examined as part of the air quality analysis for the original permit application has been reviewed to ensure currentness, quality, and completeness. All additions and deletions to this inventory have been incorporated into the modeled inventory for this administrative change request air quality analysis. The entire inventory is shown in Tables A-1 through A-12.

The Alaska DEC and EPA Region X were contacted to determine whether any additional sources should be included in the analysis. No additional sources were identified.

Prudhoe Bay sources are approximately 36 kilometers from the Kuparuk sources, and their impact in the vicinity of the Kuparuk sources will be small. However, Prudhoe Bay sources are included, where necessary, to ensure a complete inventory.

1.3 Proposed Changes

The current Kuparuk River Unit facilities design does not change the basic character of the Kuparuk River Unit production plan. Gas-fired heaters and turbines will continue to be the primary sources of atmospheric emissions, although there are differences in the numbers of various units and the distribution of the production facilities in the oil field. Table 1-1 presents a comparison of the total emissions as currently proposed and as currently permitted and demonstrates that the currently proposed emissions are lower for each pollutant. Table 1-2 shows the currently proposed emissions distribution by source type.

The regional location of the Kuparuk River Unit will not change; however, changes in the number and location of sources within the individual production facilities in the oil field will occur. The location of the Kuparuk River Unit is shown in Figure 1-1.

The new oil field development plan calls for four facilities rather than the previusly permitted three facilities. The production facilities will be named Central Production Facility-1 (CPF-1), Central Production Facility-2 (CPF-2), Central Production Facility-3 (CPF-3), and the Oliktok Point Facility (OP). The previously permitted facilities were the Central Production Facility-1, the Central Production Facility-2, and the Central Production Facility-3. The currently proposed locations of the facilities in the oil field are shown in Figure 1-2.

TABLE 1-1. POTENTIAL EMISSIONS FROM THE PROPOSED FACILITY (TONS/YR)

Pollutant	February 1983 Permitted Emissions	Currently Proposed[a]
NO_x	14,122	12,926
SO_2	85	84
PM	344	340
VOC	51	47[b]
CO	2,789	2,564

[a]Currently proposed emissions were estimated by the same methods as used by EPA Region X for the February 1983 PSD permit.

[b]Volatile Organic Compound (VOC) emissions are based on 10 percent of total hydrocarbon emissions.

TABLE 1-2. EMISSIONS DISTRIBUTION COMPARISON BY SOURCE TYPE (TONS/YR)

Pollutant	February 1983 PSD Permit			Currently Proposed Sources		
	Turbines	Heaters	Incinerator	Turbines	Heaters	Incinerator
NO_x	13,730	384	8	12,378 -1362	540 +156	8
SO_2	72	9	4	65.5 -6.5	14.5 +5.5	4
PM	293	39	12	266 -27	62 +23	12
VOC	50	0.5	0.5	45.8 -4.2	0.9 +.4	0.5
CO	2,730	42	17	2,479.3 -250.7	68.1 +26.1	17

540
384
156

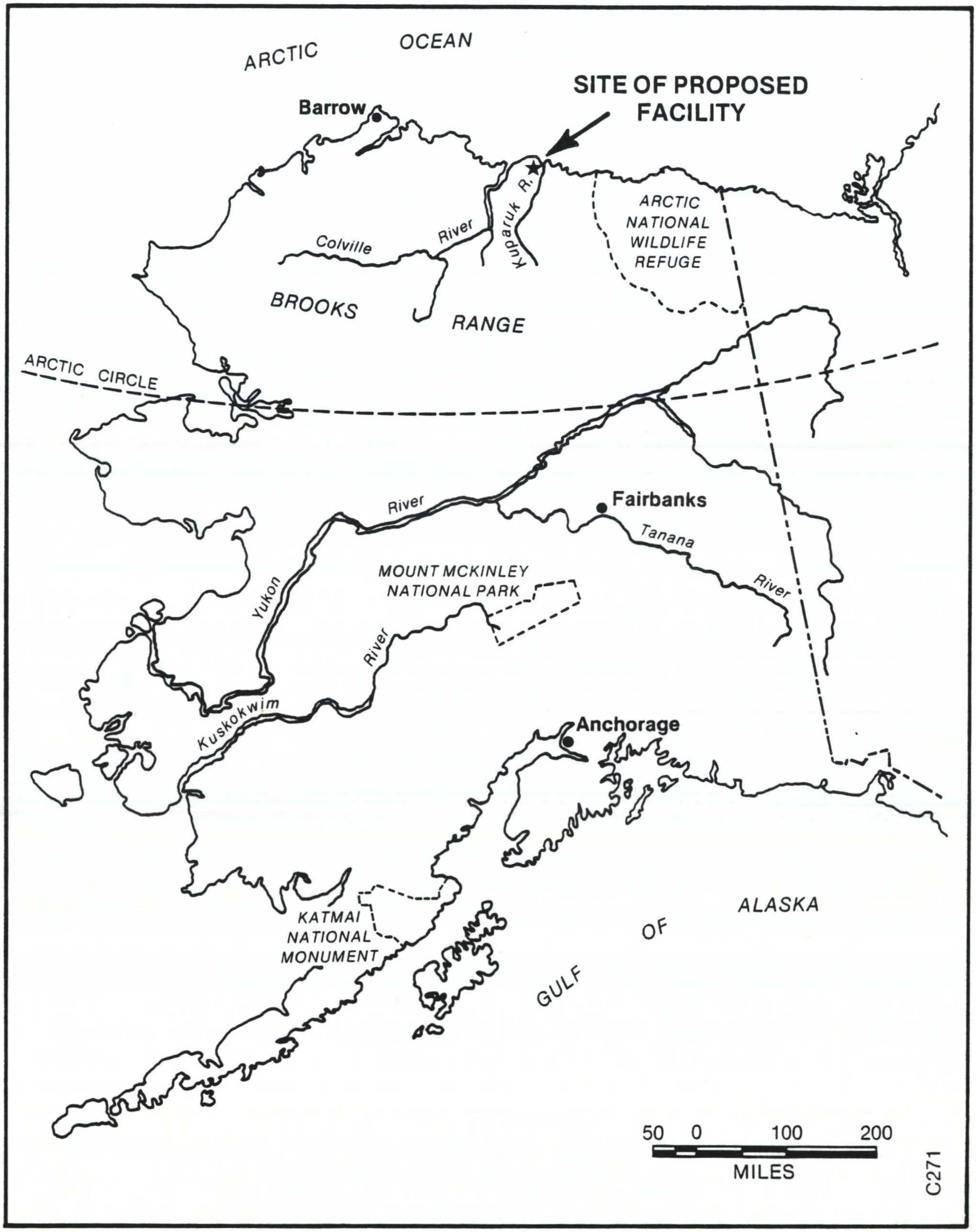

Figure 1-1. Location of the Kuparuk Area

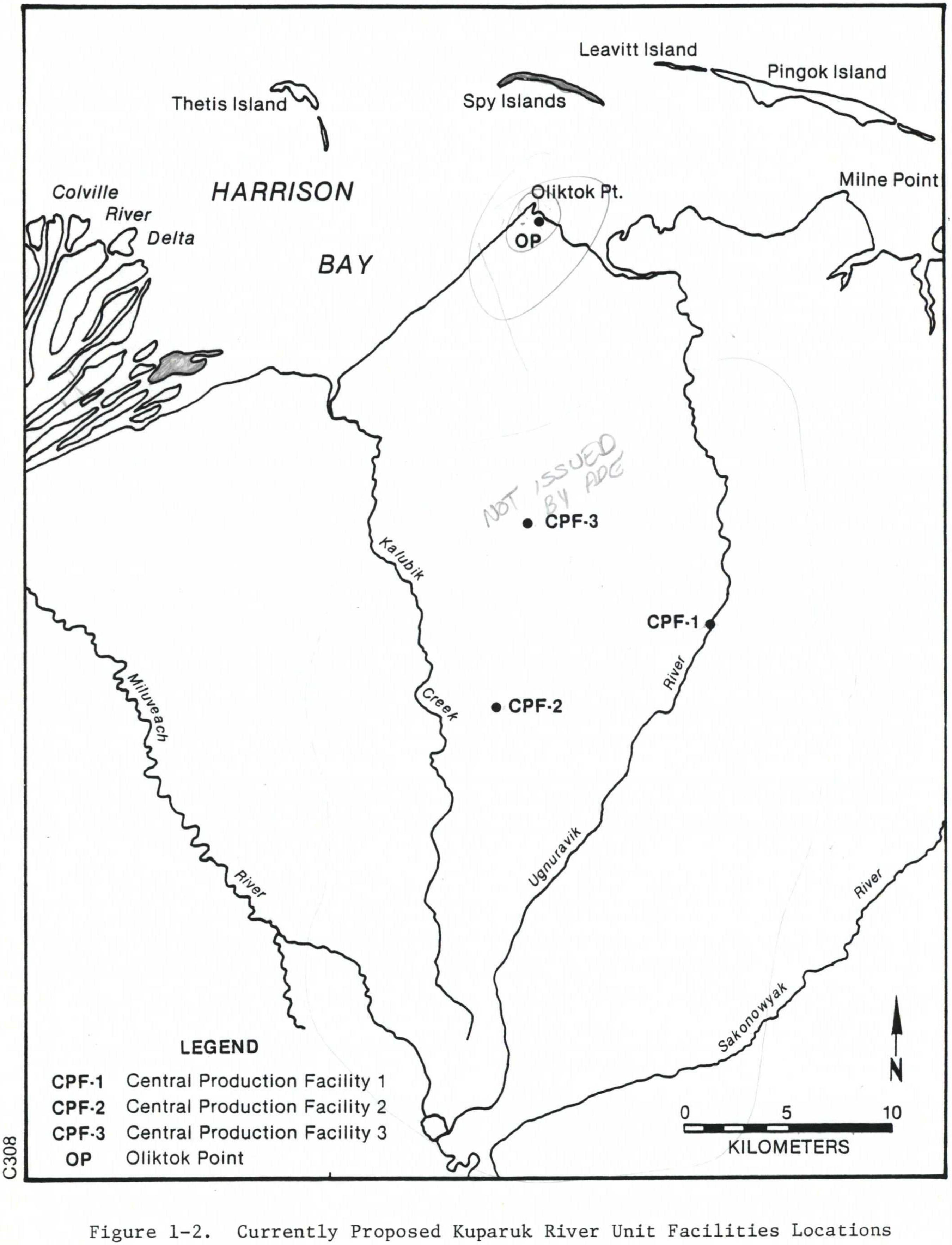

Figure 1-2. Currently Proposed Kuparuk River Unit Facilities Locations

Gas Turbines

The total number of turbines proposed for the Kuparuk River Unit expansion will be reduced from 46 to 45. The turbines range in capacity from 5 MHP to 34 MHP with a total rating of 518 MHP. The previously permitted turbine capacity was 570 MHP. The updated equipment list is shown in Table 1-3. Table 1-4 shows in detail all of the additions and deletions proposed for the KRU.

Heaters

A total of 71 space and process heaters will be installed in the Kuparuk River Unit as part of this revised permit application. Total revised heater capacity is 1045 MM Btu/hr. Previously sixty heaters were permitted for a total heater capacity of 650 MM Btu/hr. The natural gas composition is identical to that previously permitted and is shown in Appendix B.

Heater emission rates are presented in Table A-12 of Appendix A. Emission rates are calculated in a manner identical to that in the original permit application. Sample calculations appear in Appendix B.

Combined Waste Incinerator

A 765 lb/hr combined waste incinerator is proposed for CPF-1 in the February 1983 permit application. No stack parameter or emission rate changes are proposed for this source.

TABLE 1-3. KUPARUK RIVER UNIT SOURCE COMPARISON

Previously Permitted Facilities Source List			Revised Facilities Source List		
Location	Number of Units	Description	Location	Number of Units	Description
Central Production Facility-1	6	5 MHP Turbines	Central Production Facility-1	6	5 MHP Turbines
	3	14 MHP Turbines		2	14 MHP Turbines
	8	34 MHP Turbines		7	34 MHP Turbines
	21	10 MM Btu/hr Heaters[a]		21	10 MM Btu/hr Heaters[a]
	1	765 lb/hr Incinerator		1	765 lb/hr Incinerator
	1	40 MM Btu/hr Heater		1	40 MM Btu/hr Heater
				2	20 MM Btu/hr Heaters
Central Production Facility-2	10	5 MHP Turbines	Central Production Facility-2	10	5 MHP Turbines
	4	14 MHP Turbines		3	14 MHP Turbines
	18	10 MM Btu/hr Heaters[a]		18	10 MM Btu/hr Heaters[a]
	1	20 MM Btu/hr Heater		1	20 MM Btu/hr Heater
				4	20 MM Btu/hr Heaters
Central Production Facility-3	10	5 MHP Turbines	Central Production Facility-3	10	5 MHP Turbines
	5	14 MHP Turbines		5	14 MHP Turbines
	18	10 MM Btu/hr Heaters[a]		18	10 MM Btu/hr Heaters[a]
	1	20 MM Btu/hr Heater		1	20 MM Btu/hr Heater
			Oliktok Point Facility	2	5 MHP Turbines
				2	40 MM Btu/hr Heaters
				3	65 MM Btu/hr Heaters

[a]The 10 MM Btu/hr heaters are assigned to the production facilities for dispersion modeling purposes. In actuality, they will be constructed at sites throughout the Kuparuk Oil Field.

state memo 6 1220 MM BTU
2 @ 5 MHP

Oliktok Point is part of the H_2O Flood permit. ADEC has already issued a discharge permit for this point source avoiding the need for the source to undergo PSD review

Ray Nye

TABLE 1-4. COMPARISON OF CURRENTLY PERMITTED AND PROPOSED ENGINEERING REFINEMENT CAPACITIES AND EMISSIONS IN THE KUPARUK RIVER UNIT

Status	Facility	Permit	UTM Coordinates Easting (km)	UTM Coordinates Northing (km)	Equivalent Number of Units[a]	Modeled Equivalent Unit Capacity MHP	Modeled Equivalent Unit Capacity MM Btu/hr	Emissions Rate (ton/year) NO	Emissions Rate (ton/year) PM	Emissions Rate (ton/year) SO_2
Currently Permitted Source Deletions	CPF-1	KRU 2/83	401.25	7804.25	1	34	-	819	18	4
	CPF-1	KRU 2/83	401.25	7804.25	1	14	-	337	7	2
	CPF-2	KRU 2/83	391.43	7800.45	1	14	-	337	7	2
	Total					62	-	1593	32	8
Proposed KRU Engineering Refinement Sources	CPF-1	Proposed KRU Administrative Change	402.52	7804.079	2	-	20	17.3	2.5	0.6
	CPF-2		391.434	7800.452	4	-	20	35.1	4.7	1.1
	OP		393.286	7825.290	2	5	-	241	5.0	1.5
	OP		393.286	7825.290	2	-	40	35.1	4.7	1.1
	OP		393.284	7825.342	3	-	65	68.5	11.5	2.7
	Total					10	395	397	28.4	7.0
	Net Change					(52)	395	(1196)	(3.6)	(1.0)

[a]In order to retain production flexibility, the Unit Owners have permitted a total turbine capacity rather than specific units. Conservative modeling methods have been employed in that the stack parameters of the smallest turbine consistent with intended turbine use were modeled. The number of units is therefore the equivalent modeled number of a specific size turbine needed to produce the total permitted capacity.

2.0 DESCRIPTION OF THE EXISTING ENVIRONMENT

This section discusses the existing environment in the proposed Kuparuk Development Project area. This discussion updates the information presented in previous PSD permit applications. The main source of information used to characterize the existing air quality and meteorology of the Prudhoe Bay area is the PSD ambient monitoring program performed by the Unit Operators at Prudhoe Bay.

Beginning April 1, 1979 until March 31, 1980, the Prudhoe Bay Unit Operators conducted a one-year air quality and meteorological monitoring program. The network consisted of two remote sites designed to collect both air quality and meteorological parameters.

To support the monitoring activities, a monitoring plan entitled Ambient Air Quality and Meteorological Monitoring Plan for Prudhoe Bay, Alaska was submitted to EPA Region X and the Alaska DEC in late 1978. The monitoring plan demonstrated that all siting, operating, quality assurance, and data validation procedures employed in the network operation corresponded to guidelines established by the Environmental Protection Agency. A final monitoring report entitled Air Quality Meteorological Monitoring Study at Prudhoe Bay, Alaska was submitted to the Prudhoe Bay Unit Operators in January 1981. This report covered the period from April 1, 1979 until March 31, 1980 and presented a summary of air quality and meteorological parameters.

Based upon conversations with the EPA Region X meteorologist, data collected during the monitoring program may still adequately represent the existing meteorology and air quality of the Prudhoe Bay area. This data is therefore used in the interim to satisfy the requirement for monitoring data for PSD purposes for the present request for an administrative change to the KRU PSD permit application.

2.1 Site Topography and Land Use

The Prudhoe Bay section of the Arctic Coastal Plain is referred to as the Teshekpuk Lake section. This area is characterized by a uniformly flat terrain that slowly slopes downward to the coast of the Arctic Ocean. The elevation of the main portion of the Prudhoe Bay and Kuparuk areas are approximately 50 feet (15 meters) above mean sea level. Streams, channels, and other drainage systems are poorly defined, and small, shallow lakes, ponds, and water-filled depressions constitute a significant portion of the surface area. A majority of the area, however, consists of a vegetated peaty-bog formed on the slightly elevated areas. Permanently frozen ground underlies the entire region with the depth of the active layer (maximum depth of thaw) commonly being no more than 1.5 to 3 feet. The area is sparsely populated and is used primarily for energy-related activities and occasional subsistence game hunting and fishing. A map of the Kuparuk areas is given in Figure 1-2.

The land use of the Kuparuk Project area is predominantly rural, as determined by the urban/rural classification scheme described in the proposed Revisions to the Guidelines on Air Quality Models (EPA, 1980). Therefore, use of rural modeling techniques is appropriate for the region.

2.2 Soils and Vegetation

A description of the soil characteristics and vegetation communities in the Prudhoe Bay area is presented in Section 9.0 of the Prudhoe Bay Unit Owners' Waterflood Application (1979).

These soil and vegetation descriptions were reviewed and found to be accurate for the Kuparuk area.

2.3 Climate

A description of the general climate of the Kuparuk and Prudhoe Bay areas, including patterns of precipitation, snowfall, temperature, icing, and fog occurrence, has been presented in Section 4.2 of the Prudhoe Bay Unit Owners' Waterflood Application (1979). This climatological description has been reviewed and was found to be accurate and complete for the Kuparuk area. A brief review is presented here to allow the reader to understand the transport and dispersion conditions that occur in the Kuparuk area.

Due to the similarities in meteorological conditions at Prudhoe Bay, Kuparuk, Deadhorse, Barter Island, and Barrow, and the flat terrain at all locations, the Prudhoe Bay meteorological data form an excellent basis for describing the meteorology of the Kuparuk area.

The annual wind roses for Well Pad A and Drill Site 9 (based on one year of data) for Prudhoe Bay are presented in Figures 2-1 and 2-2. The most frequent wind directions observed at each of the Prudhoe Bay monitoring sites were from the east and east-northeast (about 40 percent of the time) with a secondary maximum from the west-southwest (about 10 to 15 percent of the time). The annual wind roses look similar to the 1976 wind rose for nearby Deadhorse Airport. (The Deadhorse and Barter Island wind roses are presented in Appendix F of this application.) The average wind direction is from the east to east-northeast for most of the year except for November through February when the average wind direction is from the southwest to west-southwest.

The annual average wind speed was 13.3 miles per hour (mph) at Well Pad A and 13.5 mph at Drill Site 9 for the monitoring period. During the same period, Point Barrow reported an average speed of 13.2 mph. The average speed for Barter Island could not be computed because of missing wind data. In general, the monthly average wind speeds showed the same trends at all of the sites. The monthly averages show consistently high speeds, over 10 mph, but they also show a fair amount of geographic variability, especially in January and December.

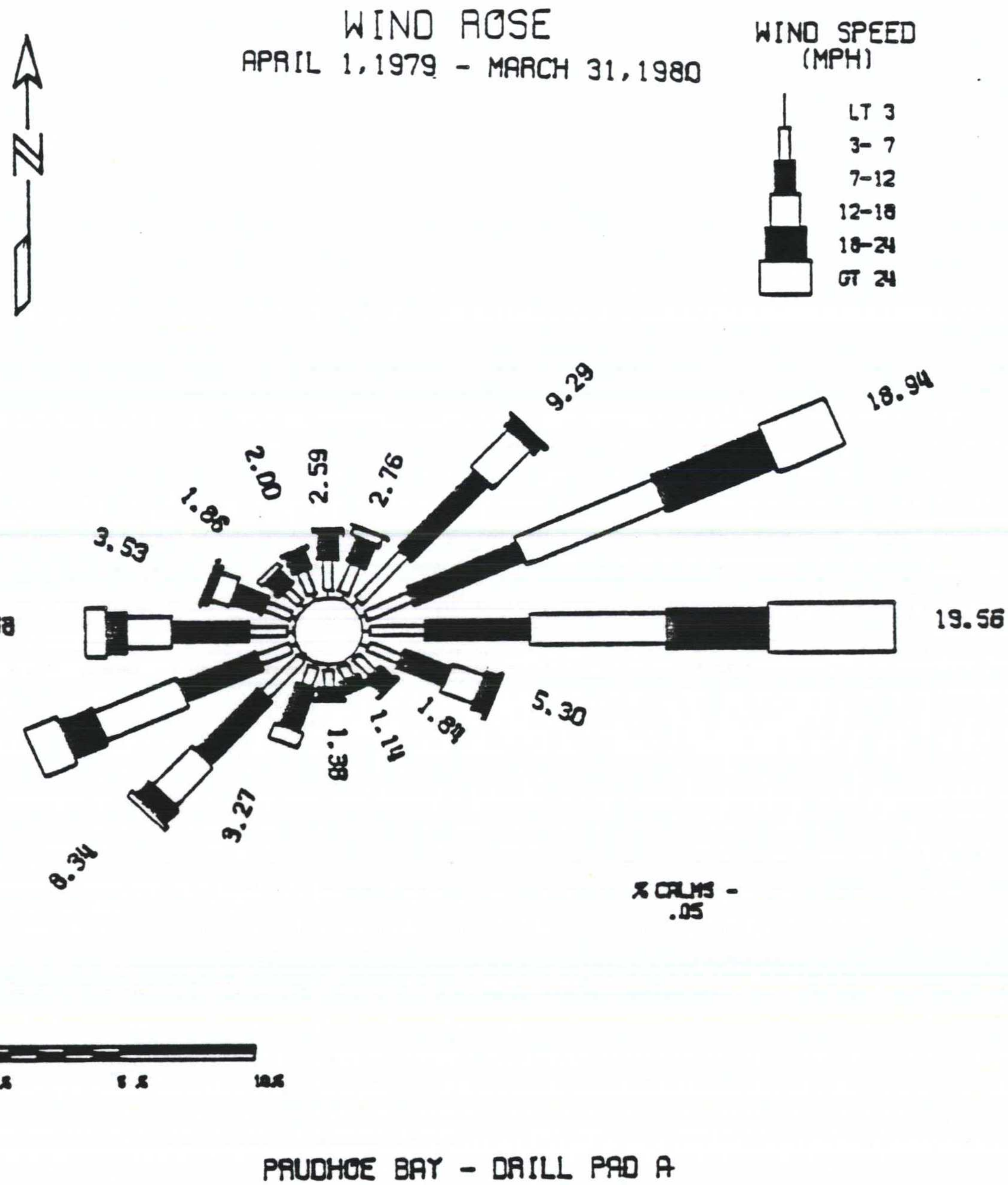

Figure 2-1. Annual Wind Rose for Drill Pad A,
Prudhoe Bay Oil Field

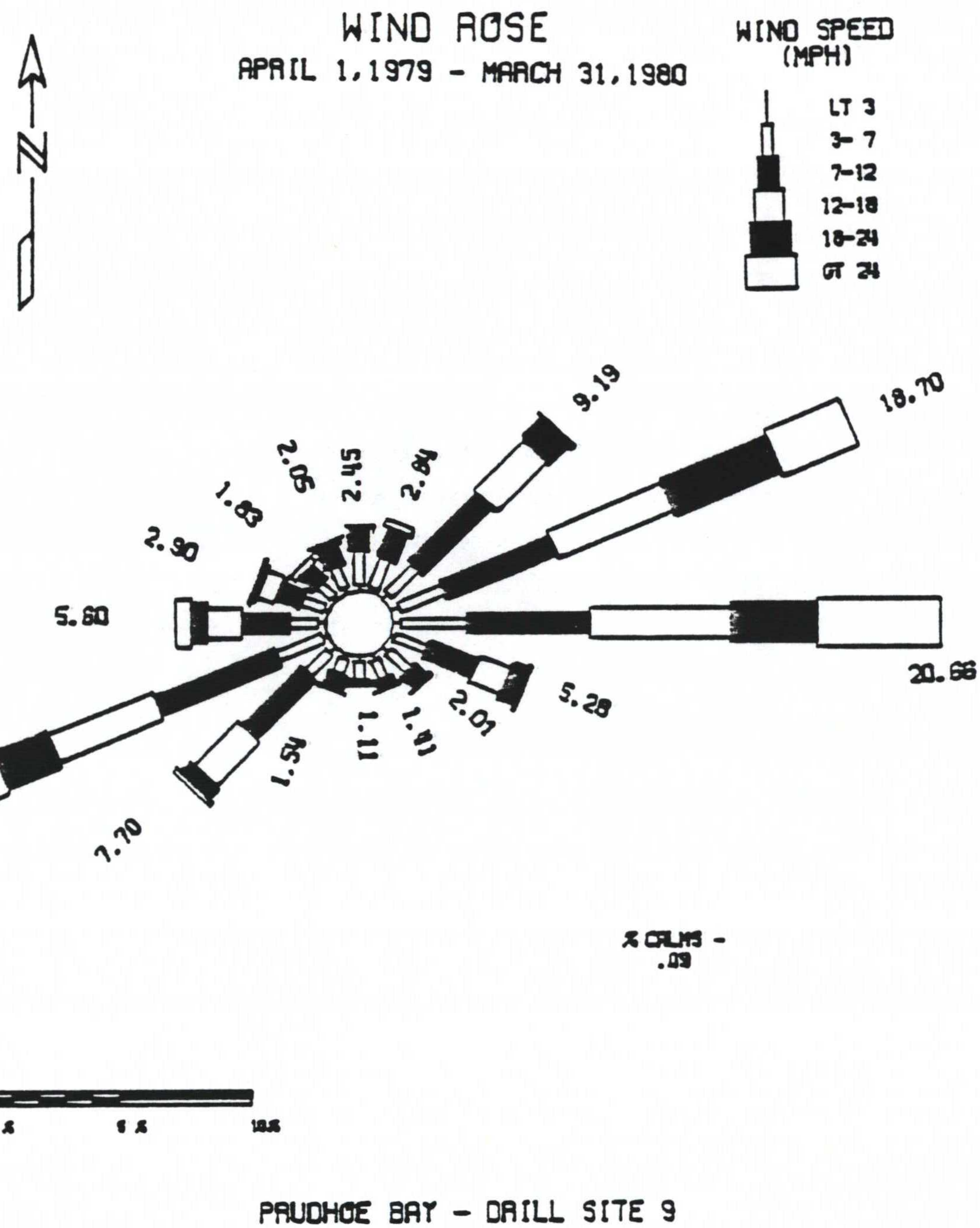

Figure 2-2. Annual Wind Rose for Drill Site 9, Prudhoe Bay Oil Field

Another comparison can be made with 1976 wind data from the nearby Deadhorse Airport. For that year the average speed was 12.8 mph which approximates the Well Pad A and Drill Site 9 speeds (13.3 and 13.5 mph) for 1979-1980.

The annual frequency distributions of the six stability classes for Prudhoe Bay are presented in Table 2-1. The processing of the on-site meteorological data to generate the annual frequency distribution is described in Appendix C. The mean wind speed associated with each stability class is also given. This table indicates that neutral stability class conditions occur about 62 percent of the time at Prudhoe Bay. According to Pasquill's standard method for determining stability classes, neutral conditions generally result from moderate to strong winds and cloudy conditions. Seasonal and annual joint frequency distributions for wind speed, wind direction, and stability class, calculated from the Prudhoe Bay data, are presented in Appendix E.

2.4 Existing Air Quality

Determination of the impact of emissions from all sources including the proposed facilities in the Kuparuk area on the National Ambient Air Quality Standards (NAAQS) requires a determination of the existing air quality of the area. This determination also illustrates the current status of compliance with the National Ambient Air Quality Standards.

Background levels, estimated from current air quality monitoring data, can be added to concentrations predicted for all the sources to predict total air quality impacts. For the purposes of this document, the term "background" refers to the contributions to total air quality from all man-made and natural sources outside of or upwind from the Prudhoe Bay area.

Air quality data collected at two monitoring sites in the Prudhoe Bay area were used to characterize existing and background air quality levels. The remote monitors were located at Drill Site 9 and Well Pad A and the instrumented tower was located at the SOHIO Base Operating Camp.

TABLE 2-1. ANNUAL FREQUENCY DISTRIBUTION OF PASQUILL STABILITY CLASSES AND WIND SPEEDS AT PRUDHOE BAY

Stability Class	Definition	Annual Frequency (%)	Average Wind Speed (mph)
A	Extremely Unstable	9.84	6.1
B	Unstable	6.28	8.4
C	Slightly Unstable	8.76	11.3
D	Neutral	62.23	14.1
E	Slightly Stable	7.08	6.7
F	Stable to Extremely Stable	5.81	3.8

Source: Radian Corporation, Air Quality and Meteorological Monitoring Study at Prudhoe Bay, Alaska (April 1, 1979 to March 31, 1980), January 1981.

The following air quality and meteorological parameters were collected at each remote site:

1. Oxides of Nitrogen (NO_x)
2. Nitric Oxide (NO)
3. Nitrogen Dioxide (NO_2)
4. Sulfur Dioxide (SO_2)
5. Ozone (O_3)
6. Carbon Monoxide (CO)
7. Total Hydrocarbons (THC)
8. Methane (CH_4)
9. Non-Methane Hydrocarbons ($THC-CH_4$)
10. Wind Speed (33 feet)
11. Wind Direction (33 feet)
12. Temperature (33 feet)
13. Total Suspended Particulates (TSP)

In addition, precipitation and visibility were measured at Drill Site 9, the upwind site. Elevated temperature stratifications and wind profiles were measured at Well Pad A, the downwind site, using an ECHOSONDE™ acoustic sounder system. This ECHOSONDE™ temperature structure data were used in estimating on-site mixing heights for the Prudhoe Bay area.

The following meteorological parameters were monitored at the 60-meter communications tower site:

Temperature	33-foot level
Temperature Difference	33 - 200 foot level
Wind Speed and Direction	146-foot level
Wind Speed and Direction	200-foot level
Horizontal Wind Direction Standard Deviation	200-foot level

Table 2-2 reports maximum and mean levels of NO_2, TSP, SO_2, CO, and ozone (O_3) measured during the 12-month monitoring period. Examination of this table shows that measured levels for all pollutants are well below those concentrations allowed by the National Ambient Air Quality Standards. The results of the monitoring program as presented in this table support the current designation of the Prudhoe Bay area as being in attainment of the NAAQS for criteria pollutants.

Background pollutant levels for use in determining total air quality impacts on NAAQS were estimated from the data collected during the Prudhoe Bay monitoring program. In order to eliminate the influence of existing Prudhoe Bay area sources on the monitors, only those periods during which the monitors were upwind of all Prudhoe Bay sources were selected for use in the background estimation. Measurements occurring during periods of east-northeast winds at Drill Site 9 and west-southwest winds at Well Pad A were used to determine the representative background concentrations. For each pollutant, the mean of all concentrations measured during the selected periods was chosen as the background applicable for all averaging times. The one exception to this rule was the mean monitored background concentration was not allowed to exceed the mean annual monitored concentration.

Based on these assumptions and methods, background concentrations were estimated for the two monitoring sites and are shown in Table 2-3.

TABLE 2-2. MEASURED POLLUTANT LEVELS ($\mu g/m^3$) IN THE PRUDHOE BAY AREA[a]

Pollutant	Monitor Location: Drill Site 9	Monitor Location: Well Pad A	National Ambient Air Quality Standards: Primary	National Ambient Air Quality Standards: Secondary
NO_2				
Arithmetic Mean[a]	3.5	4.0	100 (Annual)	100 (Annual)
TSP				
Geometric Mean[a]	6.7	11.4	75 (Annual)	60 (Annual)
24-Hour Maximum[b]	64	119	260	150
SO_2				
Arithmetic Mean[a]	0.4	0.5	80 (Annual)	---
24-Hour Maximum[b]	9.5	9.3	365	---
3-Hour Maximum[b]	13.0	25.3	---	1300
CO				
8-Hour Maximum[b]	946	856	10,000	10,000
1-Hour Maximum[b]	3430	3120	40,000	40,000
O_3				
1-Hour Maximum[c]	113	113	235	235

[a]Period of Record (4/1/79 - 3/31/80).

[b]Not to be exceeded more than once per year.

[c]Ozone standard is exceeded if the expected number of days per calendar year with maximum hourly average concentrations exceeding the standard is greater than one.

TABLE 2-3. ESTIMATED BACKGROUND AND MONITORED POLLUTANT LEVELS

	Pollutant Concentrations ($\mu g/m^3$)				
	NO_2	TSP	SO_2	CO	O_3
Annual Monitored Values					
For Source Segregation					
West-Southwesterly Winds - Well Pad A	1	15	[a]	100	51
East-Northeasterly Winds - Drill Site 9	2	5	[a]	190	51
Total Annual Mean					
Well Pad A	4	11	[a]	171	48
Drill Site 9	4	7	[a]	133	51
Estimated Background Levels[b]	2	11	--	171	51

[a]Below detectability limit of instrument.

[b]Background levels estimated by using monitored data as indicated by circled values in table.

3.0 BEST AVAILABLE CONTROL TECHNOLOGY (BACT)

Design refinements in the Kuparuk River Unit result in minimal changes to the emissions from the facilities. Since there have been no increases in the level of emissions, the types of emitting sources, or other factors which might affect the choice of emission control technology, the emission controls proposed in the February 1983 permit application still represent BACT. For comparison, both the total potential emissions for the February 1983 permit application and the currently proposed emissions are shown in Table 3-1.

In the interest of clarity, the emission controls proposed as BACT are repeated here. The discussion of alternative controls and justification of the proposed BACT can be found in the original permit application.

Proposed Controls Representing BACT

An analysis has been performed to determine BACT for the proposed facilities in a manner consistent with national and EPA Region X guidelines. The two major types of emitting sources are turbines and heaters. While these combustion sources emit significant amounts of particulate matter (PM), sulfur dioxide (SO_2), carbon monoxide (CO), and hydrocarbons (HC), the pollutants of greatest concern are the oxides of nitrogen (NO_x). BACT for gas turbines and heaters was determined according to the precedents set in the Unit Owner's PWI/LPS/AL and Waterflood permits (Permit Nos. PSD-X-80-09 and PSD-X-81-01). The controls proposed as BACT are summarized below.

Turbines

NO_x emissions from the gas turbines are controlled by use of natural gas and dry controls incorporated into the combustion chamber design. This combination will meet the NSPS[1] limit of 150 x (14.4/Y) ppmv of NO_x in the

[1]New Source Performance Standard, Standards of Performance for Stationary Gas Turbines, Subpart GG, September 10, 1979. Y = manufacturer's heat rate at manufacturer's rated load.

TABLE 3-1. PROPOSED EMISSIONS DUE TO ENGINEERING DESIGN REFINEMENTS TO KUPARUK RIVER UNIT

Pollutant	February 1983 Permitted Emissions (t/y)	Currently Proposed Emissions (t/y)	Significant Level (t/y)
CO	2,789	2,564	100
NO_x	14,122	12,926	40
SO_2	85	84	40
PM	344	340	25
VOC	51	47	40[a]

[a]VOC (Volatile Organic Compound) emissions were conservatively assumed to be 10 percent of total hydrocarbon emissions.

exhaust and should be considered BACT. Other pollutants from the gas turbines are also limited by the choice of fuel (low sulfur, low ash).

Heaters

The NO_x emissions from heaters will be minimized by burning natural gas. This fuel choice also limits emissions of SO_2 and PM since natural gas contains very little sulfur and ash forming material. The emissions of all pollutants will be limited by periodic measurements of CO or O_2 in the flue gas to ensure proper combustion conditions.

Combined Waste Incinerator

In addition to the major emission sources (turbines and heaters), a multiple chamber refuse incinerator is included in the KRU design. The incinerator will combust about 765 pounds per hour of general refuse. The proposed incinerator will comply with Alaska air quality control regulations. These regulations include a visibility reduction limitation (may not exceed 20 percent opacity for three minutes in any one hour) and a particulate matter emission limitation (0.15 grains per standard cubic foot of exhaust gas corrected to 12 percent excess CO_2). The combination of adequate additional air and combustion temperature, a properly designed mixing chamber, and/or secondary burners will be used to minimize emissions. No additional controls are proposed as BACT for the incinerator.

Besides the combustion-related emissions, there will be fugitive hydrocarbon emissions from process equipment. The process fugitive emissions will be minimized.

4.0 AIR QUALITY IMPACT ANALYSIS

4.1 Analysis Methodology

Atmospheric dispersion modeling techniques, recommended in the 1980 proposed EPA modeling guideilnes were used to predict the total air quality impacts of the engineering refinement to the Kuparuk River Unit. Annual modeling was performed using the UNAMAP 5 version of the Industrial Source Complex Long Term (ISCLT) model (Bowers, et al., 1979). Short-term modeling (24-hour averaging times or less) was performed using the same version of the Industrial Source Complex Short Term (ISCST) model. In the application of these models the building wake effects option was used, and the rural mode of the model was chosen.

To facilitate a timely review of the revised permit application, the ISCLT and ISCST models were used, as required by EPA Region X. The appropriateness of the application of these models with the building wake effects option for modeling sources in the Kuparuk area has not been conclusively demonstrated.

The ISCLT model was used to estimate annual average concentrations of NO_2, SO_2 and TSP due to the revised sources alone and in conjunction with existing and previously licensed sources. In the analysis, maximum NO_2 levels were predicted using the ozone limiting method described in the Proposed Revisions to EPA Guidelines on Air Quality Models, October 1980. Measured ozone concentrations and NO_x levels predicted by ISCLT were used in this analysis.

The ISCST model was used for calculations of 3-hour and 24-hour SO_2 concentrations and 24-hour TSP concentrations. Prudhoe Bay ambient air monitoring network data were used to estimate the contributions to total ambient short-term and long-term concentrations from background sources. The impacts of all existing, previously permitted, and proposed sources in the Prudhoe Bay area were predicted with the dispersion model.

Meteorological data were obtained from the Prudhoe Bay area PSD monitoring network, as described in the original PSD permit application. These data are the most representative source of wind stability patterns in the Kuparuk area. The Kuparuk area Central Production Facility-1 is 36 km west-northwest of Prudhoe Bay Well Pad A. The two areas are similar in terrain, land use, and distance from the Beaufort Sea. Therefore, Prudhoe Bay air quality and meteorological monitoring data were used in describing baseline conditions and in modeling air quality impacts.

For annual modeling, a joint frequency distribution of wind speed, wind direction, and stability class for a one-year period (STAR deck) was used as meteorological input. The stability classes were calculated using the modified sigma theta method described in the 1980 EPA modeling guidelines. In the application of this method, based on discussions with EPA Region X, stable conditions occurring at wind speeds greater than 11 knots were converted to stability Class D. For short-term modeling pre-processed hourly meteorological data from the Prudhoe Bay monitoring network were input to the ISCST model. Meteorological data processing is described in more detail in Appendix C. Dispersion model features are described in Appendix D.

4.2 Screening Analysis

4.2.1 Annual Screening

The updated emissions of NO_x, SO_2, and PM from the Kuparuk River Unit sources were modeled with the rural mode of ISCLT to determine the potential for significant impacts. The results are presented in Table 4-1.

The existing and previously licensed sources are located at CPF-1. The updated emissions sources in the Kuparuk River Unit are located at three production facilities (CPF-1, CPF-2, and OP). The 60 proposed drill site heaters are distributed throughout the Kuparuk River Unit. For modeling purposes, 20 drill site heaters are assumed to be colocated at each of the CPF-1,

TABLE 4-1. RESULTS OF SCREENING MODELING ANALYSES FOR EMISSIONS FROM CURRENTLY PROPOSED KUPARUK RIVER UNIT SOURCES

Pollutant	Averaging Time	Maximum Predicted Concentration (μg/m³)	Significance Level[a] (μg/m³)
NO_x	Annual	23.7	1
SO_2	Annual	0.8	1
	24-Hour	7.6	5
	3-Hour	8.8	25
TSP	Annual	2.0	1
	24-Hour	24.8	5
CO	8-Hour	<757[b]	500
	1-Hour	757	2000

[a]As defined in 1977 Clean Air Act Amendments, Federal Register, June 19, 1978.

[b]The PTPLU model predicted a 1-hour average concentration of 757 μg/m³. It is assumed that the 8-hour average concentration will be <757 μg/m³.

CPF-2, and CPF-3 production facilities. Therefore, this modeling approach is conservative.

$\underline{NO_x}$

Annual NO_x levels at receptors in the Kuparuk River Unit due to the Prudhoe Bay sources were predicted to exceed significant levels. Based on information obtained from the screening run, NO_x concentrations from the currently proposed Kuparuk River Unit sources were also predicted to exceed significant levels in the Kuparuk River Unit and at Prudhoe Bay. Therefore, ISCLT modeling runs were performed for all NO_x sources in the Prudhoe Bay and Kuparuk source inventories. From the screening run, three areas of maximum impact were identified for more refined NO_x modeling. These areas of maximum impact were located around CPF-1 and CPF-2 in the Kuparuk River Unit, and around Gathering Center 2 (GC-2) in the Prudhoe Bay Unit.

<u>TSP</u>

Particulate matter emissions from the Prudhoe Bay sources did not predict annual average TSP concentrations exceeding the annual significance level at Prudhoe Bay receptors. Annual TSP concentrations due to the Engineering Refinement to Kuparuk River Unit sources are predicted to exceed the annual significance level at receptors in the Kuparuk River Unit. Values greater than 1.0 $\mu g/m^3$ are predicted to occur near CPF-1, CPF-2, and CPF-3. These locations were further examined in the refined modeling. Table 4-1 shows the annual TSP screening results compared to the significance level.

$\underline{SO_2}$

An 8 x 5 receptor grid with 0.25 km spacing was modeled around CPF-1 and CPF-2. Additional discrete receptors were placed 0.25 km west of CPF-3 due to the higher frequency of westerly winds. Annual SO_2 concentrations due to the Engineering Refinement to the Kuparuk River Unit sources did not exceed significance levels near CPF-1 or other faciilties in the Kuparuk River Unit.

Therefore, no further annual modeling analysis is required. Table 4-1 shows the annual SO_2 screening results compared to the significance levels.

4.2.2 Short-Term Screening

Emissions of SO_2 and PM from all Kuparuk River Unit sources were input to the ISCST model to determine areas of short-term significant impact. The model was run in its rural mode with the building wake effects option selected. The ISCST source inventory considered for modeling is identical to the ISCLT source inventory. As discussed previously, this configuration is conservative.

SO_2 and PM emissions were totaled for each facility and the facilities were then ranked according to total emissions. CPF-1 will have the greatest emissions of SO_2 and PM. CPF-2 and CPF-3 have essentially identical SO_2 and PM emissions. Therefore, for the purposes of this screening analysis, if significance levels at CPF-2 were exceeded it is likely that they would also be exceeded near CPF-1 and CPF-3. Polar coordinate receptor grids were constructed around CPF-1 and CPF-2. These receptor areas were chosen because the maximum SO_2 and TSP impacts will occur near the two facilities with the largest SO_2 and PM emission rates. For this screening analysis, receptors were spaced at distances of 100, 200, 300, and 400 meters from the facility along radials spaced 10 degrees apart. Worst-case days identified by this procedure were used in the refined modeling. No PBU sources had a significant impact in the KRU for TSP or SO_2.

TSP

Model predictions of 24-hour TSP concentrations show that TSP levels due to emissions from the currently proposed Kuparuk River Unit sources will exceed the significance level of 5 $\mu g/m^3$ near CPF-1, CPF-2, and CPF-3. Therefore, more refined modeling of 24-hour TSP impacts on the NAAQS and the PSD increments is necessary. Worst-case days identified for CPF-1 in the screening analysis were used in the refined modeling. The results of the short-term screening analysis are presented in Table 4-1.

$\underline{SO_2}$

Previous modeling results for the Kuparuk River Unit sources showed the 24-hour SO_2 concentration will exceed the short-term significance level at CPF-1. Therefore, a refined impact analysis for 24-hour SO_2 concentrations is necessary only near CPF-1.

Predicted concentrations for the currently proposed Kuparuk River Unit sources did not exceed the 3-hour significance level for SO_2 at CPF-1 or CPF-2; therefore, no refined 3-hour average impact analysis is necessary.

<u>CO</u>

CO emissions were not modeled for the currently proposed Kuparuk River Unit sources. Since the original PTPLU modeling was highly conservative and total CO emissions actually decreased, the maximum predicted impact would decrease.

The worst-case 1-hour CO level presented in the February 1983 permit application was about 757 $\mu g/m^3$ (Table 4-1). This highly conservative prediction is well below the 2000 $\mu g/m^3$ 1-hour significance level. When added to the background concentration of 171 $\mu g/m^3$, the total 1-hour CO concentration of 928 $\mu g/m^3$ falls well below the NAAQS level of 40,000 $\mu g/m^3$ for a 1-hour period and 10,000 $\mu g/m^3$ for an 8-hour period. Therefore, no further CO analyses were warranted.

Ozone

Ozone impacts due to the currently proposed Kuparuk River Unit sources were not modeled because emissions of total organic compounds decreased from those proposed in the original permit application.

Potential emissions of total organic compunds currently proposed in the Kuparuk River Unit permit application will be approximately 473 tons per year. Emissions of total organic compounds proposed in the February 1983 permit application were 510 tons per year. This compares to existing total hydrocarbon emissions of 1671 tons per year calculated for sources in the Prudhoe Bay area. Since the maximum 1-hour ozone level monitored in the Prudhoe Bay unit falls well below the primary and secondary NAAQS for ozone, it is highly unlikely that the hydrocarbon emissions from the Kuparuk sources will measurably affect existing levels of ozone.

Elevated ozone levels are commonly associated with large urban areas far away from the Kuparuk River Unit. Ozone formation and its subsequent build-up is dependent in part on hydrocarbon/nitrogen oxide ratios, solar radiation, humidity, and tempterature (Revelett, 1977). The amount of ozone formed in the photochemical process is dependent not only on the absolute concentration of hydrocarbons and nitrogen oxides, but also on their ratios. It is reasonable to assume that the concentrations of these pollutants will be proportional to their emissions. The Kuparuk sources will emit much larger quantities of NO_x than hydrocarbons. If NO_x levels are high and hydrocarbons low, little ozone is produced (Westberg, 1978).

Although a precise relationship between levels of NO_x and ozone cannot be defined, quantitative estimates can be made. One study (Miller, 1978) provides field confirmation of laboratory findings which indicate that when the hydrocarbon/NO_x ratio is less than 8/1, peak ozone levels are inversely proportional to the NO_x level. Since the NO_x emissions from the revised Kuparuk River Unit sources will be larger than the hydrocarbon emissions by more than a factor of 20, the hydrocarbon/NO_x ratio is much less than the critical 8/1. Thus, it is reasonable to assume that peak ozone concentrations will decrease as the NO_x concentration increases.

A study of a large source of hydrocarbons (9000 tons per year) showed a relatively small (less than 10 ppb, in plume) increase in ozone, and indicated that the emissions had little effect on ambient oxidant levels (Westberg, 1978).

The extreme meteorological conditions of the Kuparuk River Unit also inhibit ozone formation. The intensity of solar radiation is an important parameter as it governs the photolysis rate of nitrogen dioxide, the reaction that initiates and sustains the oxidant formation process. With a maximum solar angle (elevation of sun with respect to the horizon) of approximately 45°, the light intensity at the Kuparuk River Unit is low, restricting ozone formation. The low temperature and humidity which are common to the area also constrain the build-up of ozone.

4.3 Refined Modeling

4.3.1 Annual

NO_2

NO_x emissions from the current existing, permitted, and proposed Prudhoe Bay sources and all currently proposed Kuparuk River Unit existing, previously licensed, and proposed sources were examined in refined ISCLT modeling analyses to determine maximum impacts.

The maximum annual impacts of all Kuparuk and Prudhoe Bay sources were determined from model predictions for 8 x 5 receptor grids with 0.25 km spacings constructed around CPF-1, CPF-2, and GC-2. Also, a 10 x 10 grid with a 2 km receptor spacing, and a 4 x 4 grid with 1 km spacing, covering the Kuparuk River Unit, was examined for these sources.

The sources were divided into four groups for impact determination. The first group included all currently proposed sources in the Kuparuk River Unit. Group two included the Kuparuk River Unit existing and previously licensed sources. The third group examined air quality impacts due to the curently proposed Prudhoe Bay sources. The fourth source group included all the Prudhoe Bay sources as well as all sources in the preceding groups.

The ozone limiting method described by Cole and Summerhays (1979) and recommended in the 1980 draft EPA modeling guidelines was aplied to determine maximum annual NO_2 levels from the predicted NO_x concentrations. This technique limits the formation of NO_2 to an in-stack conversion component and an atmospheric conversion component. The atmospheric component cannot exceed the maximum predicted volumetric concentration of ozone. Maximum annual ozone concentrations were determined from existing measured annual average ozone levels using the technique discussed in the <u>PSD Permit Application for New Sources to be Added to Existing and Previously Permitted Facilities in the Prudhoe Bay Unit (PSD IV)</u>.

Predicted NO_2 concentration distribution due to emissions from the currently proposed Kuparuk sources alone and for all Kuparuk and Prudhoe Bay sources are illustrated in Figure 4-1 and 4-2. Results of the modeling analysis are compared to the NAAQS for NO_2 in Table 4-2. Examination of Table 4-2 shows that the total predicted NO_2 concentration from all sources including the currently proposed Kuparuk River Unit facilities decreased to 55.8 $\mu g/m^3$ from the February 1983 permitted level of 57.6 $\mu g/m^3$.

<u>TSP</u>

The screening analysis discussed in Section 4.2 identified the Kuparuk River Unit facilities CPF-1, CPF-2, and CPF-3 as needing refined modeling.

An 8 x 5 receptor grid was modeled with a 0.25 km spacing around each facility for all Kuparuk River Unit sources. The maximum predicted TSP

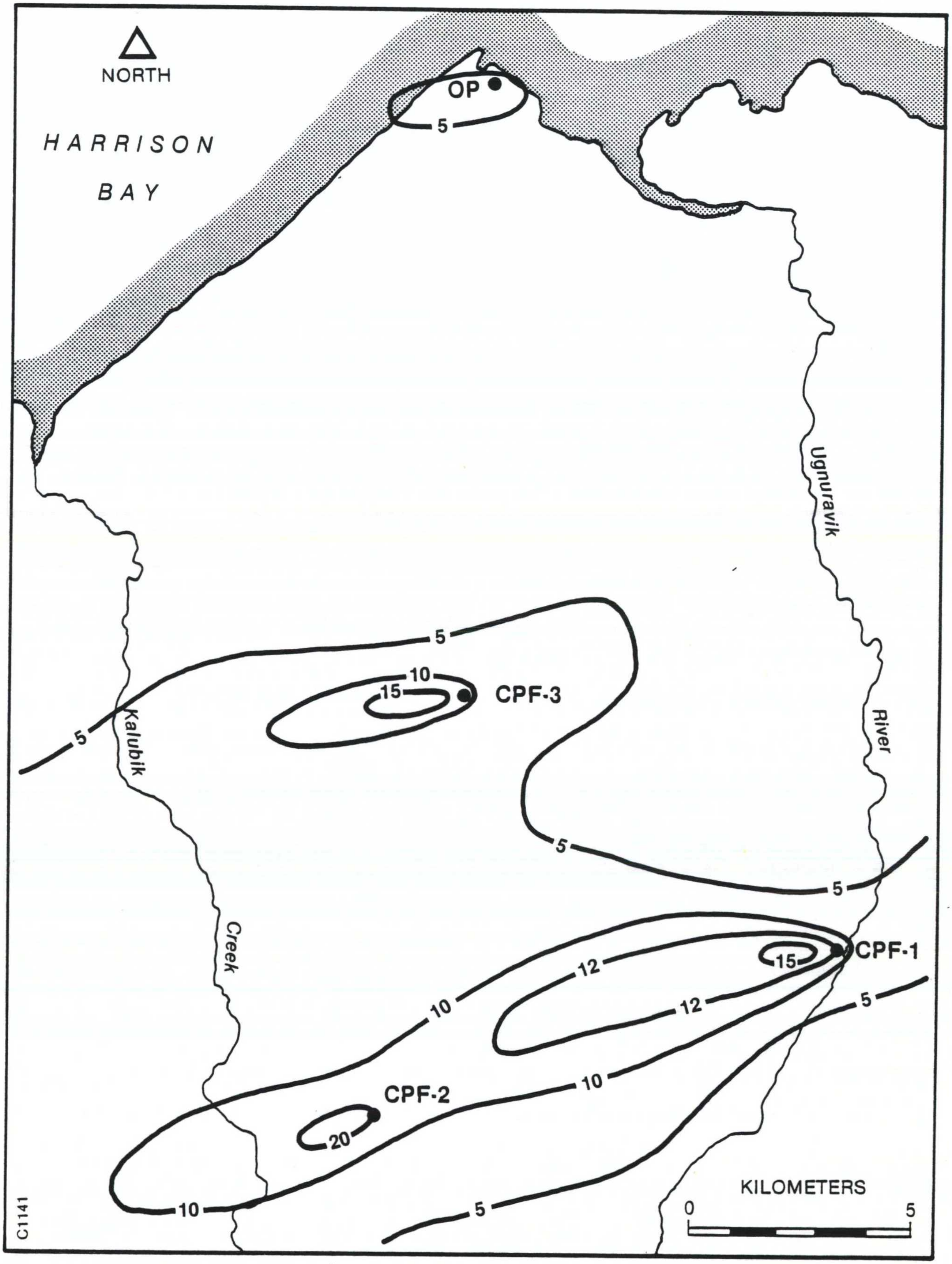

Figure 4-1. Predicted Annual NO_2 Concentrations ($\mu g/m^3$) for the Currently Proposed Kuparuk River Unit Sources

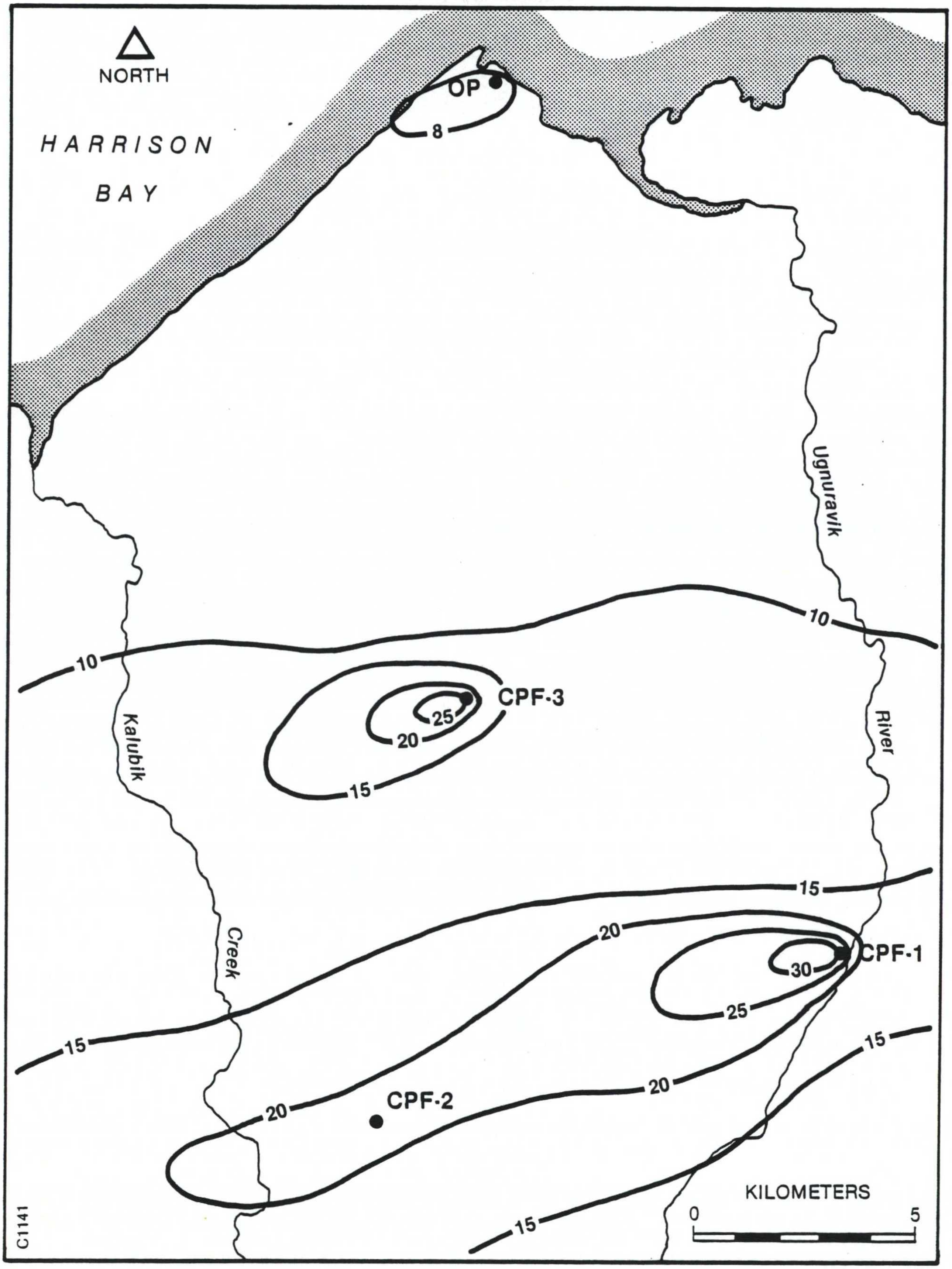

Figure 4-2. Predicted Annual NO_2 Concentrations ($\mu g/m^3$) for all Kuparuk River Unit Sources and Prudhoe Bay Sources

TABLE 4-2. MAXIMUM PREDICTED ANNUAL NO_2 CONCENTRATIONS ($\mu g/m^3$)

Pollutant Sources	Maximum Impact Receptors in Kuparuk Area CPF-1 Area	CPF-2 Area	CPF-3 Area	OP Area	Maximum Impact Receptor in Prudhoe Bay Area GC-2
Background	2.0	2.0	2.0	2.0	2.0
Kuparuk Revised Sources[a]	2.7	3.9	4.2	12.3[d]	0.1
Kuparuk Existing and Previously Licensed[a]	0.8	0.1	0.0	0.0	0.0
All Prudhoe Bay[a]	1.0	0.9	0.6	0.3[d]	8.9
Ozone Limited NO_2[b]	49.0	49.0	49.0	-	49.0
Maximum Impact on NAAQS	55.5	55.8[c]	55.6	14.6[d]	60.0
Primary and Secondary Annual NAAQS	100.0	100.0	100.0		100.0

[a]Contribution to NO_2 due to in-stack conversion (10% of total predicted NO_x concentrations).

[b]Ozone limited atmospheric NO_2 contribution as determined in PSD Permit Application for the Prudhoe Bay Unit Owners' (PSD IV), January 1981.

[c]Maximum KRU concentration reported in February 1983 application was 57.6 $\mu g/m^3$ near CPF-1.

[d]Total predicted NO_x concentrations converted to NO_2.

impacts are shown in Table 4-3. The incremental decrease in maximum annual TSP concentration due to the engineering refinement to the Kuparuk River Unit is only 1.0 $\mu g/m^3$ from the February 1983 level of 13.8 $\mu g/m^3$.

4.3.2 Short-Term

24-Hour TSP

Emissions of particulate matter from existing and currently proposed facilities in the Kuparuk River Unit were examined in a refined ISCST modeling analysis to determine maximum short-term impacts on NAAQS and PSD increments. The initial screening analysis identified 24-hour periods during which TSP concentrations due to emissions from the currently proposed sources were predicted to exceed the significance level. Meteorological conditions associated with maximum predicted 24-hour TSP concentrations occur on Julian Day 277 and are listed in Appendix E.

In the refined analysis a receptor grid with 100 m receptor spacing was examined around the areas of maximum concentrations identified for the 24-hour periods. These receptor areas are located in the vicinities of CPF-1 and CPF-2.

All Kuparuk River Unit PM emissions due to existing, previously licenses, and currently proposed sources were examined for the worst-case days at CPF-1 and CPF-2. The previously reported (February 1983) 24-hour TSP concentration was 39.6 $\mu g/m^3$ near CPF-1. The currenlty proposed KRU sources maximum 24-hour TSP concentration is 36.7 $\mu g/m^3$. The results of this 24-hour TSP analysis are presented in Table 4-4.

24-Hour SO_2

Emissions of SO_2 from existing, previously licensed, and currently proposed facilities in the Kuparuk River Unit were examined in a refined ISCST modeling analysis to determine maximum short-term impacts on NAAQS and PSD

TABLE 4-3. MAXIMUM PREDICTED ANNUAL TSP CONCENTRATIONS ($\mu g/m^3$)

Pollutant Sources	Maximum Impact Receptors in the Kuparuk Area		
	CPF-1 Area[a]	CPF-2 Area	CPF-3 Area
Background	11.0	11.0	11.0
Kuparuk Currently Proposed	1.2	1.3	1.2
Kuparuk Existing and Previously Licensed	0.6	0.04	0.0
Maximum Impact on NAAQS	12.8[b]	12.3	12.2
Primary Annual NAAQS	75	75	75
Secondary Annual NAAQS	60	60	60
Maximum Impact on PSD Class II Increment	1.8	1.3[c]	1.2
PSD Class II Increment	19	19	19

[a]Maximum impact receptor is 100 m west of CPF-1.

[b]Previously reported (February 1983) maximum concentration was 13.8 $\mu g/m^3$ near CPF-1.

[c]Maximum impact receptors are 250 m west of CPF-2.

TABLE 4-4. MAXIMUM PREDICTED 24-HOUR TSP CONCENTRATIONS ($\mu g/m^3$)

Pollutant Sources	Maximum Impact for CPF-1 Area[a]	Maximum Impact for CPF-2 Area[b]
Background	11.0	11.0
Kuparuk Existing and Previously Licensed Sources	15.8	0.0
Kuparuk Currently Proposed Sources	9.9	18.0
Impact on NAAQS	36.7[c]	29.0
Primary 24-Hour NAAQS	260	260
Secondary 24-Hour NAAQS	150	150
Impact on PSD Class II Increment	25.7	18.0
Allowable 24-Hour Class II Increment	37	37

[a]Location of maximum impact receptor is 100 m WSW of CPF-1 facility (401856.1 780404.5).

[b]Location of maximum impact receptor is 100 m WSW of CPF-2 faciilty (391340.4 7800436.4).

[c]Previously reported maximum (February 1983) concentration was 39.6 $\mu g/m^3$ near CPF-1.

increments. Worst-case days identified in the screening analysis were used in the refined modeling exercise. The meteorological conditions associated with the maximum predicted 24-hour SO_2 concentrations occur on Julian Day 277 and are listed in Appendix E. The modeling was performed in the same manner as the refined modeling for 24-hour TSP impacts. From analysis of screening results, however, only CPF-1 required refined 24-hour SO_2 modeling.

The results of this analysis are presented in Table 4-5. Results show that maximum predicted 24-hour SO_2 concentrations fall below the concentrations permitted by the primary NAAQS and by the PSD Class II increment. The 24-hour maximum SO_2 concentration reported in the February 1983 application was 20.5 $\mu g/m^3$ near CPF-1. The incremental decrease due to the engineering refinement to the Kuparuk River Unit sources is predicted to be about 8 $\mu g/m^3$.

TABLE 4-5. MAXIMUM PREDICTED 24-HOUR SO_2 CONCENTRATIONS ($\mu g/m^3$)

Pollutant Sources	Maximum 24-Hour Impact Area (CPF-1)[a]
Background[b]	5.0
Kuparuk Currently Proposed	2.4
Kuparuk Existing and Previously Licensed	5.4
Impact on NAAQS	12.8[c]
Primary NAAQS	365
Impact on PSD Class II Increment	7.8
Allowable Class II Increment	91

[a]Location of maximum impact receptor is 100 m WSW of CPF-1 facility (401856.1 780404.5).

[b]Detection limit of instrument.

[c]Previously reported maximum (February 1983) concentration was 20.5 $\mu g/m^3$ near CPF-1.

5.0 ADDITIONAL IMPACT ANALYSES

In addition to the air quality impact analyses, analyses were performed to determine impacts on soils, vegetation, and visibility, and the impacts of temporary construction emissions and emissions due to induced growth. The impacts of the proposed facilities on soils, vegetation, and visibility are not expected to be significant. Impacts due to construction are expected to be short-lived and relatively small. Finally, impacts due to induced growth are, for the most part, already included in the impact analyses performed for the proposed project.

5.1 Visibility Impacts

Particulate matter of small diameter or aerosols formed by the conversion of NO_x and SO_2 emissions to nitrates and sulfates could potentially cause some impairment to the visibility in the Lisburne area. However, the total increase in emissions of particulate matter of all size ranges should be only about 126 tons per year as a result of the proposed new sources. In addition, the maximum incremental increase in 24-hour TSP concentrations should be about 28.6 $\mu g/m^3$. Therefore, the emissions of additional particulates should not significantly impact visibility in the area.

Emissions of sulfur dioxide and nitrogen oxides from the proposed sources may undergo some conversion to sulfates and nitrates. However, SO_2 emissions increases will be small and predicted increases in ambient SO_2 concentrations will fall well below the primary NAAQS. Likewise, ambient NO_2 concentrations will be below the annual NAAQS. Therefore, SO_2 and NO_x conversion to sulfate and nitrate particulate matter is expected to be small. As a result, SO_2 and NO_x emissions are not expected to significantly affect visibility in the Kuparuk area.

A thick haze is visible over the Arctic region each spring. (Kerr, 1979; Shaw, 1982a). Visibility aloft is often reduced from more than 200 kilometers to less than 10 kilometers. Recent work by Shaw (1980, 1982b) indicates that the haze is produced by sub-micrometer sized particles of man-made origin. Trajectory analyses performed by Shaw (1982b) have traced three episodes of Arctic haze to probable transport from central Eurasia. Trajectories from the Gulf of Alaska and northwestern Canada, however, were associated with periods of excellent visibility.

The oil development on the North Slope was originally suspected of contributing to the Arctic haze, but is no longer considered to be a significant factor (Shaw, 1979). The haze has been reported since the 1950's, well before the oil development began. Vanadium and manganese are found in the haze aerosol particles, but these metals are almost non-existent in fuel oils burned in the contiguous United States and Canada.

Some haze may occur in the Kuparuk area as a result of particulate emissions from the revised Kuparuk River Unit. The potential impact of the Kuparuk River Unit emissions is not expected to produce a measurable contribution to the widespread Arctic haze.

Incremental impacts on the frequency and severity of reduced visibility are likely to be insignificant. Furthermore, the areas of major concern with respect to visibility impairment are the PSD Class I areas. No Class I areas are located within 90 kilometers of the Kuparuk area. Therefore, no impact on visibility in Class I areas is expected.

5.2 Soils and Vegetation Impacts

Soils act as significant sinks for SO_2, NO_2, and particulates. These pollutants are generally removed from the air and adsorbed on exposed surfaces. The rate of adsorption is dependent upon distance from the source, pollutant concentrations in the air, soil properties, density of vegetation cover and prevailing hydrological and meteorological conditions.

The end products of soil sorption are particulate nitrates and particulate sulfates. Predicted maximum annual concentrations of NO_2 from all sources in the Kuparuk area are projected to be 5 $\mu g/m^3$. This maximum concentration will not significantly affect soils or vegetation. The maximum NO_2 concentration will occur in the CPF-1 area and will be 57.6 $\mu g/m^3$. Of this, the Kuparuk River Unit sourcess will contribute only 4.0 $\mu g/m^3$. Increases in annual and maximum short term concentrations for other pollutants onshore will also be small and will have little impact on soils and vegetation.

The quantities of particulate nitrates and/or sulfates added to the soil and assimilated into soil-plant systems will be insignificant as compared with those normally present in the soils. Thus, the amounts of pollutants added in the vicinity of the Kuparuk River Unit should exert a negligible impact on the soils of the Kuparuk area.

There is currently no available information on the tolerance levels of high Arctic plants for the criteria air pollutants. The probable impacts of the proposed sources can, however, be inferred from the tolerance levels determined for plants native to lower latitudes. Table 4-X has been taken from Heck and Brandt (1977) and indicates the threshold level for acute toxicity to plants. Comparison of the lower range for NO_2 effects on sensitive plant taxa, 3,000 $\mu g/m^3$, to the predicted total annual NO_2 levels of 57.6 $\mu g/m^3$, would indicate no acute effects should be expected. Since predicted increases in ambient concentrations of other pollutants will be small, these increases should have no adverse impact on local vegetation.

Chronic effects from long-term exposure may be extremely difficult to either define or quantify. Long-term (22 days) exposure to low-levels of NO_2 (960 $\mu g/m^3$) has been reported to result in reduced productivity of a sensitive plant species (Jacobson and Hill, 1970). The levels of pollutant tested by far exceed the expected concentrations resulting from the proposed

Kuparuk River Unit sources. Although chronic effects due to long-term exposure to extremely low levels of NO_2 cannot be ruled out entirely, the possibility of their occurrence is remote.

Thus, in general, no noticeable adverse effect is expected due to the interaction of emissions from the new sources either on soils or vegetation.

5.3 Impacts of Anticipated Future Growth

The revised Kuparuk River Unit design will not significantly affect the number of employees required to operate the facility. Therefore, the original growth impacts analysis is still valid. Impacts due to induced growth are not expected to be significant.

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APPENDIX A
EMISSIONS INVENTORIES

APPENDIX A

Existing, Permitted, and Proposed Emissions From All Sources Modeled

Inventories of SO_2, NO_x, PM, and CO emissions from all existing and proposed sources were compiled for use in performing the air quality impact analyses. This appendix presents the inventories for these sources as well as the inventory for the proposed Endicott Development Project.

The inventories were separated into the following groups:

- Group 1. Prudhoe Bay Unit Operator's Existing Sources
- Group 2. Prudhoe Bay PSD I Sources (Permit No. PSD-X79-05)
- Group 3. Prudhoe Bay Unit Owners' PWI/LPS/AL Sources (Permit No. PSD-X80-09)
- Group 4. Prudhoe Bay Unit Owners' Waterflood Sources (Permit No. PSD-X81-01)
- Group 5. Prudhoe Bay Unit Owners' Additional Sources (1980 Equipment Exchange Analysis)
- Group 6. Proposed Northwest Alaska Pipeline Company Sources (Northwest Alaska Pipeline Company Application)
- Group 7. Prudhoe Bay Unit Owners' Proposed Additional Sources (PSD IV)
- Group 8. Endicott Development Unit Sources
- Group 9. Enhanced Oil Recovery/Central Compressor Plant Engineering Refinement to the Prudhoe Bay Unit Sources
- Group 10. Lisburne Development Project Sources
- Group 11. Kuparuk River Unit Existing Sources
- Group 12. Kuparuk River Unit Currently Proposed Sources

The inventory for Group 1 sources is identical to that reported in the Prudhoe Bay Unit Owners' Waterflood Application. This group of sources is comprised of existing oil field sources in the Prudhoe Bay Unit and existing Deadhorse area sources.

The inventory for Group 2 is similar to that reported for sources proposed in the Prudhoe Bay Unit Owners' PSD I Application. This inventory, however, does not include sources deleted from Group 2 as a result of the Prudhoe Bay Unit Owners' 1980 Equipment Exchange Analysis.

The inventories for Groups 3 and 4 are based on the emission inventories reported in the Prudhoe Bay PWI/LPS/AL Application (1980 Permit) and Waterflood Application. These inventories, however, include all changes in assumed stack parameters covered in Case 2 of the modeling analysis reported in Radian Corporation's January 14, 1980 technical document prepared for the Prudhoe Bay Unit Owners and presented to EPA Region X. These changes are also reflected in the Prudhoe Bay Unit Owners' 1980 Equipment Exchange Analysis.

The Group 5 inventory includes all additional sources reported in the Prudhoe Bay Unit Owners 1980 equipment exchange analysis.

The inventory for Group 6 consists of those sources included in the PSD Permit No. PSD-X82-05 prepared by the R. M. Parsons Company for the Northwest Alaska Pipeline Company's (NWAPC) proposed gas conditioning plant. Recently, NWAPC has submitted a modified source inventory to the ADEC for review. This modified source inventory is presented in Group 6A for informational purposes only. Only the Group 6 sources were modeled. The table shown below presents a comparison of the total emissions due to Group 6 and Group 6A sources. Group 6 sources have greater total emissions, therefore, modeling of Group 6 sources for the current air quality analysis is conservative.

NORTHWEST ALASKA PIPELINE COMPANY (NWAPC)
PERMIT NO. PSD-X82-05 AND CURRENTLY
PROPOSED EMISSIONS COMPARISON

Pollutant	Group 6 Permit No. PSD-X82-05	Group 6A Currently Proposed
NO_x	17,572.8	16,440.4
SO_2	514.5	497.2
PM	413.8	370.9
HC	789	605.5
CO	4,362.4	3,331.1

Group 7 contains the inventory for all Prudhoe Bay Unit Owners' Proposed Additional Sources (PSD IV).

Group 8 contains the inventory for the proposed Endicott Development Project sources.

Group 9 contains the deletions and additions to the entire Prudhoe Bay Unit inventory proposed as the Enhanced Oil Recovery/Central Compressor Plant Engineering Refinement to the Prudhoe Bay Unit.

Group 10 contains the inventory for the proposed Lisburne Development Project sources.

Groups 11 and 12 contain the entire inventory for the Kuparuk River Unit.

TABLE A-1

GROUP 1: EXISTING NON-INCREMENT CONSUMING SOURCES

Map ID	Source ID	UTM (km) East	UTM (km) North	NO_x Annual (g/s)	SO_2 (g/s)	Particulate Short Term (g/s)	Particulate Annual (g/s)	CO (g/s)	NMHC (g/s)	HS (m)	TS (^oK)	DS (m)	VS (m/sec)
ACT	ARCO P-357	449.50	7794.60	.434	.009	.019	.019	.032	.006	15.2	623	1.0	10.6
ACT	ARCO P-357	449.50	7794.60	.03	.005	.003	.003	.004	.001	15.2	623	.3	10.6
ACC	ARCO P-358	448.40	7794.70	2.7	.039	.117	.117	.198	.035	15.2	623	1.0	10.6
ACT	ARCO P-136	449.30	7794.40	1.33	.00	.116	.116	.00	.17	15.2	555	1.2	10.6
ACT	ARCO P-135	449.30	7794.40	.396	.113	.038	.038	.94	.706	10.7	1033	.9	6.9
FS-1	ARCO P-138	446.10	7795.10	14.8	.186	.502	.502	4.12	1.5	13.1	644	2.5	20.1
FS-1	ARCO P-138	445.90	7795.30	2.98	.00	.025	.025	.00	.38	15.2	623	.3	10.6
FS-2	ARCO P-381	449.55	7795.60	14.8	.186	.502	.502	4.12	1.5	13.1	644	2.5	20.1
FS-2	ARCO P-381	449.45	7795.60	2.98	.00	.025	.025	.00	.38	15.2	623	.3	10.6
FS-3	ARCO P-443	440.75	7795.80	14.8	.186	.502	.502	4.12	1.5	13.1	644	2.5	20.1
FS-3	ARCO P-443	440.75	7795.60	2.98	.00	.025	.025	.00	.38	15.2	623	.3	10.6
AFC	ARCO P-325	443.70	7802.20	.578	.00	.50	.50	.00	.076	16.1	611	.9	10.6
AFC	ARCO P-324	443.70	7802.20	164.0	2.12	5.58	5.58	45.70	16.7	26.8	755	2.4	50.6
AFC	ARCO P-324	443.70	7802.20	1.53	.022	.066	.066	.113	.02	9.1	519	1.1	10.6
CC-1	SOHIO P-338	435.80	7799.50	.037	.063	.176	.095	.25	.076	7.3	1088	.5	6.9
CC-1	SOHIO P-338	435.80	7799.50	.13	.064	.16	.086	.009	.032	7.3	1088	.5	7.4
CPS	SOHIO P-185	437.50	7797.20	109.2	1.403	3.70	3.70	30.30	11.4	15.8	777	2.7	50.6
CPS	SOHIO P-183	437.50	7797.20	20.31	.258	.69	.69	5.63	2.12	15.8	777	2.7	50.6
DW	DOW P-325	447.90	7792.00	1.25	.059	.044	.044	.767	.125	3.7	721	.2	15.2
DW	DOW P-325	447.90	7792.00	.078	.16	.067	.067	.006	.004	3.7	721	.2	7.4
N1	NANA P-413	447.30	7791.00	.76	.63	.011	.011	8.82	.377	20.0	450	.9	13.7
N1	NANA P-413	447.30	7791.00	.38	.32	.006	.006	4.41	.189	20.0	450	.9	7.4
PS1	ALY. P-289	439.00	7796.00	25.1	.320	.85	.85	6.99	2.55	13.7	727	3.3	22.8
PS1	ALY. P-289	439.00	7796.00	1.04	.009	.035	.035	.289	.105	13.7	727	3.3	22.8
PS1	ALY. P-289	439.00	7796.00	1.56	.022	.067	.067	.115	.02	13.7	623	1.0	10.7
PS1	ALY. P-289	439.00	7796.00	.00	.014	.001	.001	.00	.00	7.9	1144	.4	6.9
PS1	ALY. P-289	439.00	7796.00	.062	.01	.003	.003	.001	.002	7.9	1144	.4	7.4
N2	NANA P-423	444.40	7789.40	9.66	.64	.69	.69	2.09	.77	7.6	421	.5	18.3
N2	NANA P-434	444.40	7789.40	.04	.113	.707	.707	.904	.706	10.7	1033	.9	6.9
VE	VE P-482	446.00	7791.60	7.00	.47	.50	.39	1.51	.56	7.6	421	.5	15.2
VE	VE P-482	446.00	7791.60	.195	.055	.35	.35	.47	.35	10.6	1033	.9	6.9
AOC	ARCO OPS CR	449.80	7794.60	.26	.431	.047	.035	.153	.397	12.2	971	1.1	6.9
AOC	ARCO OPS CR	449.80	7794.60	.08	.038	.018	.014	.01	.043	12.2	1366	.8	7.4
SOC	SOHIO BOC	435.80	7799.50	.063	.034	.02	.02	.007	.008	12.2	1366	.5	6.9
SOC	SOHIO BOC	435.80	7799.50	.003	.052	.002	.00	.13	.404	12.2	1088	.5	7.4
SOC	SOHIO BOC	435.80	7799.50	.20	.53	.40	.009	6.91	1.14	6.7	660	.5	18.3

TABLE A-1 (Continued)

Map ID	Source ID	UTM (km) East	UTM (km) North	NO_x Annual (g/s)	SO_2 (g/s)	Particulate Short Term (g/s)	Particulate Annual (g/s)	CO (g/s)	NMHC (g/s)	HS (m)	TS (°K)	DS (m)	VS (m/sec)
CC-2	SOHIO P-374	430.00	7803.50	.03	.047	.066	.066	.187	.056	12.2	1088	.5	6.9
CC-2	SOHIO P-347	430.00	7803.50	.106	.054	.041	.041	.009	.022	12.2	1088	.5	7.4
	DH. ARPRT	445.00	7789.00	15.67	1.14	1.12	1.12	3.38	1.25	10.7	428	.6	22.8
FC	FRONTIER	445.70	7791.20	7.83	.52	.56	.56	1.69	.63	10.7	428	.5	18.3
	ACC	427.00	7801.80	2.61	.17	.19	.19	.56	.21	10.7	428	.3	18.3
FC	Downtown	446.50	7791.20	13.06	.87	.93	.93	2.82	1.04	10.7	428	.6	15.2
CC-1	SOHIO GC1	434.75	7800.90	2.83	.049	.121	.121	.20	.04	10.0	506	.61	14.2
CC-1	SOHIO GC1	434.60	7800.95	.38	.005	.02	.02	.02	.004	18.0	506	.41	8.6
CC-2	SOHIO GC2	429.95	7801.90	2.83	.049	.121	.121	.20	.04	10.0	506	.6	14.2
CC-2	SOHIO GC2	430.05	7801.90	.38	.005	.02	.02	.02	.004	18.0	506	.4	8.6
CC-3	SOHIO GC3	436.65	7798.60	2.83	.049	.121	.121	.20	.04	10.0	506	.6	14.2
CC-3	SOHIO GC3	436.60	7798.55	.38	.005	.02	.02	.02	.004	18.0	506	.4	8.6
CPS	SOHIO CPS	437.50	7797.20	.28	.005	.012	.012	.02	.004	18.0	506	.4	3.5

TABLE A-2

GROUP 2: PRUDHOE BAY UNIT OWNERS INCREMENT I SOURCES

Map ID	UTM (km) East	UTM (km) North	NO_x Annual (g/s)	SO_2 (g/s)	Particulate Short Term (g/s)	Particulate Annual (g/s)	CO (g/s)	NMHC (g/s)	HS (m)	TS (°K)	DS (m)	VS (m/sec)
SOHIO GC2	430.10	7801.85	35.33	0.462	1.20	1.20	9.00	3.58	16.7	470	1.71	50.0
SOHIO GC3	436.70	7798.50	8.80	0.47	.30	.30	2.45	.90	16.7	755	2.69	35.0
SOHIO CPS	437.50	7797.20	35.90	0.133	1.25	1.25	10.31	3.77	16.7	755	2.80	42.0

TABLE A-3

GROUP 3: PRUDHOE BAY UNIT OWNERS INCREMENT II SOURCES

Map ID	UTM (km) East	UTM (km) North	NO_x Annual (g/s)	SO_2 (g/s)	Particulate Short Term (g/s)	Particulate Annual (g/s)	CO (g/s)	NMHC (g/s)	HS (m)	TS (^oK)	DS (m)	VS (m/sec)
GC-1	434.70	7801.05	5.20	.027	.115	.115	.95	.17	16.7	830	.88	50.0
GC-1	434.75	7801.00	1.04	.005	.03	.03	.20	.03	16.7	830	.55	50.0
GC-1	434.65	7801.10	67.20	.408	1.67	1.67	12.54	2.27	16.7	470	1.71	50.0
GC-1	434.75	7801.10	2.04	.039	.115	.115	.20	.03	7.6	623	.94	10.6
GC-1	434.60	7801.05	.12	.002	.007	.007	.012	.002	18.3	623	.43	10.6
GC-1	434.65	7800.90	7.39	.138	.42	.42	.72	.127	7.6	623	.73	10.6
GC-2	429.90	7801.85	5.20	.027	.115	.115	.95	.17	16.7	830	.88	50.0
GC-2	430.00	7801.85	1.04	.005	.03	.03	.20	.03	16.7	830	.55	50.0
GC-2	430.05	7801.80	126.52	1.065	3.17	4.30	23.58	4.28	16.7	470	1.71	50.0
GC-2	429.95	7801.80	3.05	.089	.17	.172	.29	.05	7.6	623	.94	10.6
GC-2	430.00	7801.75	7.39	.222	.42	.42	.72	.127	7.6	623	.73	10.6
GC-2	429.90	7801.75	.12	.003	.007	.007	.012	.002	18.3	623	.43	10.6
GC-3	436.70	7798.45	5.20	.027	.12	.12	.95	.17	16.7	830	.88	50.0
GC-3	436.65	7798.50	1.04	.005	.03	.03	.20	.03	16.7	830	.55	50.0
GC-3	436.80	7798.45	67.20	.559	1.67	2.31	12.54	2.27	16.7	470	1.71	50.0
GC-3	436.60	7798.45	2.01	.039	.115	.115	.20	.07	7.6	623	.94	10.6
GC-3	436.70	7798.40	.12	.002	.007	.007	.012	.002	18.3	623	.43	10.6
GC-3	436.75	7798.60	7.39	.222	.42	.42	.72	.127	7.6	623	.73	10.6
DRILL PAD E	437.10	7804.70	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
DRILL PAD F	433.50	7804.40	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
DRILL PAD G	435.00	7802.30	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
DRILL PAD D	434.90	7799.60	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
DRILL PAD H	430.90	7800.10	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
DRILL PAD J	430.90	7803.20	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
DRILL PAD M	426.40	7804.20	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
DRILL PAD N	428.10	7802.50	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
DRILL PAD R	428.50	7804.20	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
DRILL PAD Q	431.00	7801.60	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
DRILL PAD S	423.50	7804.20	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
DRILL PAD Y	431.20	7796.80	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3

TABLE A-3 (Continued)

Map ID	UTM (km) East	UTM (km) North	NO_x Annual (g/s)	SO_2 (g/s)	Particulate Short Term (g/s)	Particulate Annual (g/s)	CO (g/s)	NMHC (g/s)	HS (m)	TS (^oK)	DS (m)	VS (m/sec)
DRILL PAD A	434.00	7796.60	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
DRILL PAD C	437.30	7799.70	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
DRILL PAD X	437.00	7793.30	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
DRILL PAD B	437.00	7796.60	0.24	.005	.014	.014	.023	.004	14.0	506	.6	14.3
CCP	443.70	7802.20	18.58	.115	.46	.46	3.45	.63	16.7	470	1.71	50.0
CCP	443.70	7802.20	.63	.018	.03	.03	.06	.01	9.1	519	.5	14.1
FS-1	446.00	7795.25	7.44	.044	.18	.18	1.40	.25	16.8	748	1.0	29.7
FS-1	446.00	7795.20	80.29	.479	1.84	1.84	14.96	2.73	16.7	470	1.71	50.0
FS-2	449.55	7795.50	107.05	.639	2.45	2.45	19.96	3.62	16.7	470	1.71	50.0
FS-2	449.55	7795.40	7.44	.044	.18	.18	1.40	.25	16.8	748	1.0	29.7
FS-2	449.45	7795.50	2.39	.05	.14	.14	.23	.04	15.0	530	.9	12.0
FS-3	440.75	7795.70	107.05	.639	2.45	2.45	19.96	3.62	16.7	470	1.71	50.0
FS-3	440.65	7795.80	7.44	.044	.18	.18	1.40	.25	16.8	748	1.0	29.7

TABLE A-4

GROUP 4: PRUDHOE BAY UNIT OWNERS WATERFLOOD SOURCES

Map ID	Source ID	UTM (km) East	UTM (km) North	NO_x Annual (g/s)	SO_2 (g/s)	Particulate Short Term (g/s)	Particulate Annual (g/s)	CO (g/s)	NMHC (g/s)	HS (m)	TS (^oK)	DS (m)	VS (m/sec)
SWT	SWTR TRT	443.00	7810.10	7.88	.144	.45	.45	.78	.14	28.0	530	1.4	12.0
SWT	SWTR TRT	443.00	7810.10	2.85	.05	.16	.16	.28	.05	28.0	530	1.0	12.0
IPE	E INJ PLT	445.50	7795.00	59.47	1.243	1.44	1.44	11.08	2.01	21.0	450	2.4	16.2
IPW	W INJ PLT	435.00	7800.70	59.47	1.243	1.44	1.44	11.08	2.01	21.0	450	2.4	16.2
IPW	W INJ PLT	445.50	7795.00	2.39	.05	.14	.14	.23	.04	15.0	530	.9	12.0
IPE	E INJ PLT	435.00	7800.70	2.39	.05	.14	.14	.23	.04	18.3	530	.9	12.0

TABLE A-5

GROUP 5: PRUDHOE BAY UNIT OWNERS SWAP ADDITION SOURCES

Map ID	UTM (km) East	UTM (km) North	NO_x Annual (g/s)	SO_2 (g/s)	Particulate Short Term (g/s)	Particulate Annual (g/s)	CO (g/s)	NMHC (g/s)	HS (m)	TS (°K)	DS (m)	VS (m/sec)
SIPW	435.00	7800.70	11.9	.071	.29	.29	2.22	.40	22.2	450	0.76	29.0
SIPW	435.00	7800.70	18.0	.337	1.04	1.04	1.70	.30	22.2	450	1.77	29.9
GC-2	429.95	7801.70	5.6	.036	.14	.14	1.04	.19	22.2	450	1.16	31.4
GC-3	436.70	7798.55	5.6	.036	.14	.14	1.04	.19	22.2	450	1.16	31.4
STP	443.00	7810.10	7.2	.213	.41	.41	.68	.12	22.2	450	0.91	14.4
SIPE	445.50	7795.00	11.9	.071	.29	.29	2.22	.40	22.2	450	0.76	29.0
SIPE	445.50	7795.00	18.0	.331	1.04	1.04	1.70	.30	22.2	450	1.77	29.9
SIPE	445.50	7795.00	18.6	.072	.45	.45	3.47	.63	22.2	450	1.77	29.9

TABLE A-6

GROUP 6: NORTHWEST ALASKAN PIPELINE COMPANY PERMITTED SOURCES

Map ID	UTM (km) East	UTM (km) North	NO_x Annual (g/s)	SO_2 (g/s)	Particulate Short Term (g/s)	Particulate Annual (g/s)	CO (g/s)	NMHC (g/s)	HS (m)	TS (°K)	DS (m)	VS (m/sec)
AGCF	443.13	7802.39	38.53	.76	.74	.74	9.24	1.68	28.96	605.2	3.81	15.24
AGCF	443.17	7802.20	38.53	.76	.74	.74	9.24	1.68	28.96	605.2	3.81	15.24
AGCF	443.12	7802.40	21.98	.44	.42	.42	4.94	.90	28.96	609.7	2.89	15.24
AGCF	443.16	7802.21	21.98	.44	.42	.42	4.94	.90	28.96	609.7	2.89	15.24
AGCF	443.30	7802.33	96.31	1.90	1.85	1.85	23.10	4.20	28.96	605.2	3.81	15.24
AGCF	443.38	7802.05	128.64	2.52	2.52	2.52	30.96	5.64	28.96	605.2	4.02	15.24
AGCF	443.31	7802.15	42.88	.84	.84	.84	10.32	1.88	28.96	605.2	4.02	15.24
AGCF	443.31	7802.11	16.47	.32	.32	.32	3.76	.66	28.96	781.3	2.84	15.24
AGCF	443.07	7802.24	79.29	1.56	1.53	1.53	19.08	3.48	28.96	605.2	4.47	15.24
AGCF	443.23	7801.97	3.51	.99	.45	.45	.48	.09	38.10	421.9	1.16	15.24
AGCF	443.22	7801.97	7.44	2.07	.93	.93	1.05	.19	38.10	449.7	1.74	15.24
AGCF	443.33	7802.21	6.51	1.83	.81	.81	.93	.17	38.10	421.9	1.58	15.24
AGCF	441.50	7802.40	.30	.012	.01	.01	.011	.002	28.96	421.9	0.53	15.24
AGCF	441.60	7802.30	.35	.05	.05	.05	.00	.00	28.96	421.9	0.15	3.05
AGCF	441.60	7802.40	1.42	.016	.05	.05	.58	.107	28.96	605.7	0.86	15.24
AGCF	439.50	7796.80	.16	.05	.05	.05	1.14	.20	28.96	605.7	0.49	15.24

TABLE A-6A

GROUP 6A: CURRENTLY PROPOSED NORTHWEST ALASKAN PIPELINE COMPANY SOURCES

Map ID	UTM (km) East	UTM (km) North	NO_x (g/s)	SO_2 (g/s)	PM (g/s)	HS (m)	TS (°K)	DS (m)	VS (m/s)
1	442.887	7802.753	19.3	0.006	0.43	25.0	598.0	4.38	15.24
2	442.625	7802.357	39.2	0.70	0.72	36.9	583.0	3.74	15.39
3	443.038	7802.445	61.2	1.11	1.17	36.9	591.3	3.89	15.24
4	442.659	7802.357	34.4	0.62	0.64	35.1	571.9	3.52	15.24
5	442.973	7802.424	34.4	0.62	0.64	35.1	571.9	3.52	17.37
6	442.735	7802.223	110.5	2.05	2.05	38.1	598.0	3.94	17.37
7	442.909	7802.238	86.0	1.56	1.60	27.7	598.0	3.94	15.24
8	442.671	7802.668	71.1	1.32	1.32	24.1	699.7	4.77	15.24
9	442.958	7802.553	11.6	6.01	1.44	27.3	500.8	2.44	15.24
10	442.716	7802.561	4.78	0.30	0.60	24.7	557.4	1.75	15.24
11	441.739	7802.213	0.34	0.00	0.04	15.2	866.3	0.51	15.24
12	442.424	7802.495	0.113	0.00	0.02	6.4	499.7	0.14	15.24
13	441.738	7802.110	0.037	0.00	0.00	6.4	499.7	0.13	15.24
14	439.576	7795.689	0.02	0.00	0.00	15.2	499.7	0.13	15.24

TABLE A-7

GROUP 7: SOHIO & ARCO PSD IV SOURCES

Map ID	UTM (km) East	UTM (km) North	NO_x Annual (g/s)	SO_2 (g/s)	Particulate Short Term (g/s)	Particulate Annual (g/s)	CO (g/s)	NMHC (g/s)	HS (m)	TS (°K)	DS (m)	VS (m/sec)
GC-1	434.70	7800.95	11.53	.068	.28	.28	2.08	.38	22.2	450	1.16	31.4
GC-1	434.65	7801.00	26.90	.159	.66	.66	4.85	.88	22.2	450	1.98	33.2
GC-2	430.05	7801.70	17.29	.102	.43	.43	3.12	.57	22.2	450	1.16	31.4
GC-2	430.10	7801.75	34.59	.204	.85	.85	6.24	1.13	22.2	450	1.98	31.4
GC-3	436.75	7798.50	5.76	.034	.14	.14	1.04	.19	22.2	450	1.16	31.4
GC-3	436.80	7798.55	46.12	.272	1.13	1.13	8.32	1.51	22.2	450	1.98	33.2
IPW	435.00	7800.70	19.22	.113	.47	.47	3.47	.63	22.2	450	1.98	33.2
FS-1	446.00	7795.15	3.84	.023	.09	.09	.69	.13	22.2	450	1.16	31.4
FS-1	445.90	7795.10	3.02	.057	.17	.17	.29	.05	22.2	450	.91	14.4
FS-1	446.10	7795.30	27.67	.163	.68	.68	4.99	.91	22.2	450	1.98	33.2
FS-2	449.45	7795.40	7.69	.045	.19	.19	1.39	.25	22.2	450	1.16	31.4
FS-3	440.65	7795.70	7.69	.045	.19	.19	1.39	.25	22.2	450	1.16	31.4
FS-3	440.65	7795.60	3.02	.057	.17	.17	.29	.05	22.2	450	.91	14.4
SWT	443.00	7810.10	24.60	.145	.60	.60	4.44	.81	22.2	450	.76	29.0

TABLE A-8

GROUP 8: PROPOSED ENDICOTT DEVELOPMENT PROJECT POINT SOURCE EMISSIONS INVENTORY

Map ID	UTM Easting (km)	UTM Northing (km)	No. of Units Modeled	Source Type	Stack Characteristics: Stack Height (m)	Temp (°K)	Diam (m)	Vel (m/s)	Total Emissions (modeled Emissions): NO_x (g/s)	SO_2 (g/s)	NMHC (g/s)	CO (g/s)	PM (g/s)	Building Dimensions Used for Modeling: Height (m)	Length (m)	Width (m)
PIB	466.30	7803.10	2	75 mm Btu/hr gas MEG heater	24.1	422	1.04	10.4	4.6	0.07	0.06	0.34	0.3	18.0	30.5	24.4
PIB	466.30	7803.10	2	2.2 mm Btu/hr gas TEG heater	20.7	506	0.24	8.9	0.13	0.002	0.002	0.01	0.01	17.7	30.5	24.4
WID	467.34	7804.84	2	22 mm Btu/hr SWI diesel heater	25.9	810	0.90	8.2	0.90	0.02	0.04	0.20	0.08	22.9	30.5	24.4
PIB	466.30	7803.10	2	drilling rig engines	7.3	491	0.90	13.6	70.0	<.001	3.6	3.68	<.001	4.3	30.5	24.4
PIB,SIA,SIC	466.30	7803.10	8	2.5 mm Btu/hr wellhouse heater	10.4	623	0.25	11.0	0.61	0.01	0.01	0.05	0.04	7.3	30.5	24.4
PIB	466.30	7803.10	6	10 MW power generation gas turbine	34.0	450	1.5	32.5	61.8	0.4	2.0	11.2	1.5	17.4	30.5	24.4
PIB	466.30	7803.10	2	36 MHP LPS/WGC gas turbine	33.5	450	2.3	38.5	55.3	0.3	1.8	10.0	1.4	30.5	30.5	24.4
PIB	466.30	7803.10	6.6	5 MHP WGC gas turbine	30.0	450	1.16	31.4	25.4	0.17	0.83	4.6	0.62	17.7	30.5	24.4
PIB	466.30	7803.10	4.8	10 MHP WGC gas turbine	30.0	450	1.45	31.0	36.9	0.24	1.20	6.6	0.90	17.7	30.5	24.4
MCC	461.08	7794.57	2	2 MHP power generation diesel turbine	18.3	755	0.76	25.6	2.14	1.76	0.18	0.48	0.16	15.3	30.5	24.4
MCC	461.08	7794.57	1	Combined waste Incinerator	18.3	1280	0.76	11.4	0.136	0.183	0.097	0.324	0.225	15.3	30.5	24.4
PIB	466.30	7803.10	1	Combined waste Incinerator	18.3	1263	0.45	11.4	0.053	0.027	0.033	0.110	0.077	15.3	30.5	24.4
WID	467.34	7804.84	1	300 HP SWI diesel pump engine	22.9	588	0.25	4.42	0.46	0.002	0.008	0.033	0.05	19.9	30.5	24.4

TABLE A-9

GROUP 9: EOR/CCP ENGINEERING REFINEMENT TO THE PRUDHOE BAY UNIT

			UTM Coordinates		Stack Characteristics				Total Emissions (Modeled Emissions)			Building Dimensions Used for Modeling		
Status	Facility	Permit	Easting (km)	Northing (km)	Stack Height (m)	Temp (°K)	Diam (m)	Vel (m/s)	NO_x (g/s)	SO_2 (g/s)	PM (g/s)	Height (m)	Length (m)	Width (m)
Currently	GC-2	PSD II	430.050	7801.800	16.7	470.2	1.7	50.0	59.32	0.362	1.5	13.7	33.5	24.2
Permitted	GC-3	PSD IV	436.800	7798.550	22.2	450.0	1.9	33.2	46.12	0.272	1.13	19.2	33.5	24.2
Source Deletions	FS-1	PDS IV	445.900	7795.100	22.2	450.0	0.9	14.4	3.02	0.057	0.17	19.2	33.5	24.2
	FS-1	PDS IV	446.100	7795.300	22.2	450.0	1.9	33.2	27.67	0.163	0.68	19.2	33.5	24.2
	FS-2	PDS II	449.550	7795.000	16.7	470.2	1.7	50.0	26.76	0.164	0.612	13.7	33.5	24.2
	FS-3	PDS IV	440.650	7795.600	22.2	450.0	0.9	14.4	3.02	0.057	0.17	19.2	33.5	24.2
	IPE	PDS III	445.500	7795.000	21.0	450.2	2.4	16.2	11.89	0.073	0.288	18.0	33.5	24.2
	CCP	PSD II	443.700	7802.203	9.1	519.2	0.5	14.1	0.63	0.012	0.03	6.1	33.5	24.2
	SWT	PSD III	443.000	7810.133	28.0	530.2	1.4	12.0	7.88	0.151	0.45	25.0	30.5	24.2
	SWT	PSD III	443.000	7810.133	28.0	530.2	1.0	12.0	2.85	0.055	0.16	25.0	30.5	24.2
	SWT	PSD IV	443.000	7810.100	22.2	450.0	0.7	29.0	24.60	0.145	0.60	19.2	30.5	24.2
	SWT	SWAP	443.000	7810.133	22.2	450.0	0.9	14.4	7.20	0.137	0.41	19.2	33.5	24.2
Proposed EOR/CCP	SWT	Proposed	442.870	7812.340	33.8	450.0	0.91	14.4	67.20	0.326	0.994	19.2	33.5	24.2
Engineering	EOR	PBU	443.370	7802.100	22.2	450.0	1.9	33.2	55.34	0.326	1.36	19.2	33.5	24.2
Refinement	EOR	Amendment	443.430	7802.160	22.2	450.0	1.9	33.2	55.34	0.326	1.36	19.2	33.5	24.2
Sources	CCP	"	443.660	7802.160	22.2	450.0	1.9	33.2	83.01	0.489	2.04	19.2	33.5	24.2
	EOR	"	443.370	7802.240	22.2	450.0	0.9	14.4	6.96	0.130	0.40	15.2	33.5	13.7

[1] In order to retain production flexibility, the Unit Owners have permitted a total turbine capacity rather than specific units. Conservative modeling methods have been employed in that the stack parameters of the smallest turbine consistent with intended turbine use were modeled. The number of units is therefore the equivalent modeled number of a specific size turbine needed to produce the total permitted capacity.

TABLE A-10

GROUP 10: PROPOSED LISBURNE PROJECT POINT SOURCE EMISSIONS INVENTORY

Map ID	UTM Easting (km)	UTM Northing (km)	No. of Units Modeled	Source Type	Stack Characteristics: Stack Height (m)	Temp (°K)	Diam (m)	Vel (m/s)	Total Emissions (modeled Emissions): NO_x (g/s)	SO_2 (g/s)	HC (g/s)	CO (g/s)	PM (g/s)	Building Dimensions Used for Modeling: Height (m)	Length (m)	Width (m)
LPC	445.99	7798.61	2	10 mm Btu/hr gas TEG reboiler	35.9	589	0.6	5.5	0.42	0.397	0.008	0.107	0.015	29.9	51.8	18.3
LPC	446.09	7798.51	2	30 mm Btu/hr utility heaters	35.9	533	1.1	6.1	1.28	1.192	0.026	0.320	0.046	18.3	23.2	25.6
LPC	445.99	7798.51	1	40 mm Btu/hr NGL frac--tionator	35.9	533	1.4	6.1	0.85	0.795	0.017	0.214	0.031	18.3	23.2	25.6
LPC	445.99	7798.41	2	70 mm Btu/hr process heaters	35.9	644	1.7	6.2	2.99	2.782	0.060	0.748	0.107	18.3	23.2	25.6
LPC	446.09	7798.41	2	10 MHP refrig. turbine	35.9	728	1.7	25.6	12.60	3.530	0.504	2.780	0.379	19.2	48.8	16.4
LPC	446.09	7798.61	3	20 MHP generator	35.9	783	2.3	25.6	37.80	10.59	1.510	8.320	1.135	26.8	44.5	16.4
LPC	445.99	7798.41	3	32 MHP injection turbines	37.4	728	2.7	32.6	60.48	16.95	2.420	13.320	1.820	19.2	48.8	16.4
L1	444.86	7803.92	1	25 mm Btu/hr drill site heaters	14.6	700	1.1	7.5	0.53	0.807	0.011	0.134	0.019	—	—	—
L2	446.80	7800.34	1	25 mm Btu/hr drill site heaters	14.6	700	1.1	7.5	0.53	0.807	0.011	0.134	0.019	—	—	—
L3	450.54	7799.59	1	25 mm Btu/hr drill site heaters	14.6	700	1.1	7.5	0.53	0.807	0.011	0.134	0.019	—	—	—
L4	454.30	7798.81	1	25 mm Btu/hr drill site heaters	14.6	700	1.1	7.5	0.53	0.807	0.011	0.134	0.019	—	—	—
L5	453.57	7803.65	1	25 mm Btu/hr drill site heaters	14.6	700	1.1	7.5	0.53	0.807	0.011	0.134	0.019	—	—	—
L6	449.10	7804.35	1	25 mm Btu/hr drill site heaters	14.6	700	1.1	7.5	0.53	0.807	0.011	0.134	0.019	—	—	—

TABLE A-11

GROUP 11: KUPARUK RIVER UNIT DEVELOPMENT EXISTING AND PREVIOUSLY LICENSED SOURCES

Map ID	Description	UTM (km) East	North	NO_x g/s	SO_2 g/s	PM g/s	CO g/s	HC g/s	HS (m)	TS (°K)	DS (m)	VS (m/s)
CPF	4-5 MHP turbines w/WHR	401.25	7804.24	13.6	0.08	0.28	2.72	0.48	18.4	475	1.2	29.9
CPF	2-14 MHP turbines w/WHR	401.25	7804.24	19.4	0.1	0.42	3.88	0.70	24.4	500	2.2	22.4
CPF	5-10 MMBtu/hr heaters	401.24	7804.25	1.3	0.02	0.085	0.094	0.015	17.4	450	0.8	8.6
CPF	1-20 MMBtu/hr heater	401.24	7804.25	0.53	0.008	0.034	0.039	0.007	26.2	450	0.9	6.0
CPF	1-1300 lb/hr incinerator	401.24	7804.25	0.25	0.2	0.58	0.82	0.025	12.3	1144	1.2	12.4

TABLE A-12

GROUP 12: KUPARUK RIVER UNIT DEVELOPMENT CURRENTLY PROPOSED SOURCES - 3/84

Map ID	UTM (km) East	UTM (km) North	NO_x (g/s)	SO_2 (g/s)	PM (g/s)	CO (g/s)	HC (g/s)	HS (m)	TS (°K)	DS (m)	VS (m/s)
CPF-1	402.097	7803.965	13.38	0.08	0.28	2.72	0.48	18.4	475	1.2	29.9
	402.122	7803.965	3.34	0.02	0.07	0.68	0.12	18.4	475	1.2	29.9
	402.122	7803.940	3.34	0.02	0.07	0.68	0.12	18.4	475	1.2	29.9
	401.956	7803.972	19.4	0.10	0.42	3.9	0.70	24.4	500	2.2	22.2
	402.235	7804.180	23.56	0.12	0.51	4.71	0.86	24.4	500	2.2	43.9
	402.285	7804.180	23.56	0.12	0.51	4.71	0.86	24.4	500	2.2	43.9
	402.335	7804.180	23.56	0.12	0.51	4.71	0.86	24.4	500	2.2	43.9
	402.385	7804.180	23.56	0.12	0.51	4.71	0.86	24.4	500	2.2	43.9
	402.235	7804.130	23.56	0.12	0.51	4.71	0.86	24.4	500	2.2	43.9
	402.285	7804.130	23.56	0.12	0.51	4.71	0.86	24.4	500	2.2	43.9
	402.335	7804.130	23.56	0.12	0.51	4.71	0.86	24.4	500	2.2	43.9
	402.385	7804.130	0	0	0	0	0	24.4	500	2.2	43.9
	402.250	7804.110	2.65	0.08	0.36	0.40	0.06	17.4	450	0.8	8.2
	402.157	7803.991	0.5	0.015	0.089	0.078	0.014	26.2	450	0.9	6.0
	402.011	7804.076	0.23	0.121	0.345	0.486	0.151	12.8	1255	0.76	15.4
CPF-2	391.43	7800.450	34.65	0.20	0.70	6.8	1.19	18.4	475	1.2	29.9
	391.43	7800.450	29.09	0.15	0.63	5.79	1.05	24.4	500	2.2	22.4
	391.43	7800.450	2.27	0.068	0.306	0.32	0.03	17.4	450	0.8	8.2
	391.43	7800.450	0.25	0.008	0.084	0.04	0.01	26.2	450	0.9	5.7
CPF-3	393.00	7810.000	34.65	0.20	0.70	6.8	1.19	18.4	475	1.2	29.9
	393.00	7810.000	48.49	0.25	1.05	9.66	1.75	24.4	500	2.2	22.4
	393.00	7810.000	2.27	0.68	0.306	0.32	0.03	17.4	450	0.8	8.2
	393.00	7810.000	0.25	0.008	0.034	0.04	0.01	26.2	450	0.9	5.7
OP	393.286	7825.290	1.01	0.032	0.136	4.73	0.024	27.5	455	1.4	20.7
	393.284	7825.342	1.97	0.078	0.332	11.54	0.058	35.6	374	1.5	7.6
	393.286	7825.290	6.93	0.04	0.140	4.87	0.240	27.5	455	1.4	20.7

APPENDIX B

COMBUSTION AND EMISSIONS CALCULATIONS

PROJECT NAME - Kuparuk River Unit

<u>Combustion Calculation</u>

Fuel Composition supplied by Arco:

Component	Molecular Weight	Mole %
CO_2	44.1	1.3
N_2	28.016	0.7
CH_4	16.043	78.0
C_2H_6	30.070	10.0
C_3H_8	44.097	10.0
H_2S	34.00	0.002 (20 ppm) negligible

Heating Value of Fuel = 1100 Btu/scf @ 25°C, 1 atm
(supplied by Arco)

$$PV = nRt$$

$$V = \frac{nRt}{P}$$

$$V = \frac{(\text{lb mole})(1.31 \text{ atm ft}^3/\text{lb mole}°\text{K})(298.2°\text{K})}{1 \text{ atm}}$$

$$V = 390.6 \text{ scf/lb mole fuel @ } 298.2°\text{K, 1 atm}$$

$$\begin{array}{llcll}
0.78 & + 1.56 & & 0.78 + 1.56 & \text{(moles)} \\
CH_4 & + 2O_2 & \rightarrow & CO_2 + 2H_2O & \\
0.1 & + 0.35 & & 0.2 + 0.3 & \\
C_2H_6 & + 3.5O_2 & \rightarrow & 2CO_2 + 3H_2O & \\
0.1 & + 0.5 & & 0.3 + 0.4 & \\
C_3H_8 & + 5O_2 & \rightarrow & 3CO_2 + 4H_2O & \\
\hline
0.98 & + 2.41 & \rightarrow & 1.28 + 2.26 & \text{(mole totals)}
\end{array}$$

PROJECT NAME - Kuparuk River Unit

O_2 needed = 2.41 moles/mole fuel

$N_2 = \frac{79}{21} \times 2.41 = 9.07$ moles/moles fuel

CO_2 formed = 1.28 moles/moles fuel

H_2O formed = 2.26 moles/moles fuel

PROJECT NAME - Kuparuk River Unit

<u>Combustion Calculation</u> (based on fuel analysis supplied in original Kuparuk permit application).

<u>We have that</u>;

$$\underbrace{(0.02 \text{ inert} + 0.98 \text{ moles})}_{\text{fuel}} + \underbrace{2.41 \text{ moles}}_{O_2} \rightarrow \underbrace{1.28 \text{ moles}}_{CO_2} + \underbrace{2.26 \text{ moles}}_{H_2O} + \underbrace{0.02 \text{ moles}}_{\text{inert fuel}}$$

<u>From the Above Equation</u>:

2.41 moles O_2 req'd (theoretical)/mole fuel

$$\text{Theoretical air} = \overset{21\%}{O_2} + \overset{79\%}{N_2}$$

$$\text{Theoretical } N_2 = \frac{79}{21} O_2 = \frac{79}{21}(2.41) = 9.07 \text{ moles } N_2 \text{ req'd/mole fuel}$$

$$\text{Theoretical air} = \overset{O_2}{2.41} + \overset{N_2}{9.07} = 11.48 \text{ moles/mole fuel}$$

With complete combustion with 15% O_2 in flue gas, the total lb moles O_2 (dry) per lb mole of fuel, X is calculated by the following equation.

$$0.15 = \frac{X \text{ lb mole } O_2}{X \text{ lb moles } O_2 + 1.28 \text{ lb moles } CO_2 + 9.07 + \frac{79}{21} X \text{ lb moles } NO_2}$$

$$0.15 = \frac{X}{4.76\ X + 10.36}$$

$$X = 0.15\ (4.76\ X + 10.36)$$

$$X = 0.71\ X + 1.55$$

$$1X - 0.71\ X = 1.55$$

$$0.29\ X = 1.55$$

$$X = 5.34 \text{ lb moles } O_2/\text{lb moles fuel}$$

Therefore, the flue gas products dry are:

Component	lb moles flue gas/ lb moles fuel
CO	1.28
N_2: (3.76 x 5.34) + 9.07	29.15
O_2	5.34
	35.77 $\frac{\text{lb moles flue gas}}{\text{lb moles fuel}}$

or

$$\frac{\text{scf flue gas}}{\text{scf fuel}}$$

Sample Calculation of Exit Velocity

$$\frac{4727 \text{ scf fuel}}{\text{hr}} \times \frac{14.25 \text{ scf flue}}{\text{scf fuel}} = 67832.5 \text{ scf flue/hr}$$

$$Q = 67832.5 \text{ scf flue gas/hr} \times \frac{\text{hr}}{60 \text{ min}}$$

$$\frac{\text{min}}{60\text{s}} \times \frac{450°\text{K}}{298°\text{K}} \times \frac{\text{m}^3}{35.31 \text{ ft}^3} = 0.806 \text{ m}^3/\text{s}$$

$Q = 0.81 \text{ m}^3/\text{s}$ $\qquad$ $D = 0.56 \text{ m}$

$Q = \frac{\pi}{4} D^2 \, Vs$ $\qquad$ $Vs = \frac{(4)Q}{\pi D^2}$

$Vs = 3.29 \text{ m/s}$

PROJECT NAME - Kuparuk River Unit

Gas Heater Emission Calculations

The potential emissions of pollutants from gas heaters were calculated using the following equation:

$$\text{Emission Rate (TPY)} = \text{Heat Rate of Heater}^{(1)} \times \frac{\text{scf}}{1100 \text{ Btu}} \times \frac{8760 \text{ hr}}{\text{yr}} \times \text{EF}^{(2)} \times \frac{\text{ton}}{2000 \text{ lb}}$$

Emission factors were taken from Table 1.4-1 of AP-42.

$PM = 15\ lb/10^3\ ft^3$ Highest of 5-15 range

$CO = 17\ lb/10^3\ ft^3$;

$HC\ (as\ CH_4) = 3\ lb/10^3\ ft^3$;

$NO_x\ (as\ NO_2) = 0.1\ lb/MMBtu^{(3)}$

---

(1) Fired Duty

(2) $EF = \text{Emission Factor}\ \frac{\text{lbs pollutant}}{10^3 ft^3 \text{ gas burned}}$

(3) NO_x emission factor from the approved original Kuparuk PSD permit.

PROJECT NAME - Kuparuk River Unit

SO_2 Emission Factor for Gas Combustion

Emission Assumptions:

1. H_2S in fuel = 20 ppm

2. $H_2S + 3/2\ O_2 \rightarrow SO_2 + H_2O$

3. 1 mole H_2S = 1 mole SO_2

4. Standard Conditions = 25°C, 1 atm

$$SO_2 \text{ Emission Factor} = \frac{20 \text{ lb moles } H_2S}{10^6 \text{ lb moles fuel}} \times \frac{\text{lb mole } SO_2}{\text{lb mole } H_2S} \times 64 \frac{\text{lb } SO_2}{\text{lb mole } SO_2} \times$$

$$\frac{\text{lb mole fuel}}{390.6 \text{ scf}} = \frac{3.3 \text{ lb } SO_2}{10^6 \text{ scf}} \times \frac{\text{scf}}{1100 \text{ Btu}}$$

$$= 0.0030 \frac{\text{lb } SO_2}{10^6 \text{ Btu}}$$

$$= 1.4 \frac{\text{g } SO_2}{10^6 \text{ Btu}}$$

PROJECT NAME - Kuparuk River Unit

NO_x Emissions From Gas Turbines

NO_x flue gas concentration = 150 ppmv in flue gas on a dry basis at 15% excess O_2

9433 Btu/hp-hr = maximum heat rate for turbines in this permit.

Dry

$$\frac{\text{lb moles flue gas}}{\text{hp-hr}} = \frac{9433\ \text{Btu}}{\text{hp-hr}} \times \frac{\text{lb moles fuel}}{390.6\ \text{scf fuel}} \times \frac{36.3\ \text{moles flue gas}}{\text{lb mole fuel}} \times$$

$$\times \frac{\text{scf fuel}}{1100\ \text{Btu}} = \frac{0.7969\ \text{lb moles flue gas}}{\text{hp-hr}}$$

$$\frac{\text{lb}}{1000\ \text{hp-hr}} = \frac{0.7969\ \text{lb moles flue gas}}{\text{hp-hr}} \times \frac{0.000150\ \text{lb moles}\ NO_2}{\text{lb moles flue gas}}$$

$$\times \frac{46.008\ \text{lb}\ NO_2}{\text{lb mole}} \times 1000 = \frac{5.5\ \text{lb}\ NO_x}{1000\ \text{hp-hr}}$$

$$5000\ \text{hp} \times \frac{5.5\ \text{lbs}\ NO_x}{1000\ \text{hp-hr}} = 27.5\ \frac{\text{lb}\ NO_x}{\text{hr}}$$

$$27.5\ \frac{\text{lb}\ NO_x}{\text{hr}} \times 453.59\ \frac{\text{g}}{\text{lb}} \times \frac{\text{hr}}{3600\text{s}} = 3.46\ \frac{\text{g}\ NO_x}{\text{s}}$$

Emissions of SO_2, PM, CO, and HC from the 5 MHP, 14 MHP, and 34 MHP turbines were obtained from the original Kuparuk permit application.

PROJECT NAME - Kuparuk River Unit

Incinerator Emissions (Waste Combustion with Supplemental Natural Gas)

Calculation factor from AP-42 Table 2.1-1 Refuse Incinerator

PM = 7 lb/ton

SO_2 = 2.5 lb/ton

CO = 10 lb/ton

HC = 3 lb/ton

NO_2 = 3 lb/ton

$$0.385 \text{ ton/hr} \times 7 \text{ lb/ton} = 2.7 \frac{\text{lb PM}}{\text{hr}} = 0.34 \text{ g/s}$$

$$0.385 \text{ ton/hr} \times 2.5 \text{ lb/ton} = 1 \frac{\text{lb } SO_2}{\text{hr}} = 0.12 \text{ g/s}$$

$$0.385 \text{ ton/hr} \times 10 \text{ lb/ton} = 3.8 \frac{\text{lb CO}}{\text{hr}} = 0.48 \text{ g/s}$$

$$0.385 \text{ ton/hr} \times 3 \text{ lb/ton} = 1.2 \frac{\text{lb HC}}{\text{hr}} = 0.15 \text{ g/s}$$

$$0.385 \text{ ton/hr} \times 3 \text{ lb/ton} = 1.2 \frac{\text{lb } NO_2}{\text{hr}} = 0.15 \text{ g/s}$$

Calculation factor from AP-42 Table 1.4-1 Natural Gas Combustion

PM = 15 lb/10^6 scf fuel

SO_2 = 3.3 lb/10^6 scf fuel (based on 20 ppm H_2S)

CO = 17 lb/10^6 scf fuel

HC = 3 lb/10^6 scf fuel

NO_2 = 230 lb/10^6 scf fuel

PROJECT NAME - Kuparuk River Unit

2750 scf fuel/hr x 15 lb/10^6 scf fuel = $\frac{0.04 \text{ lb PM}}{\text{hr}}$ = 0.005 g/s

2750 scf fuel/hr x 3.3 lb/10^6 scf fuel = $\frac{0.009 \text{ lb } SO_2}{\text{hr}}$ = 0.001 g/s

2750 scf fuel/hr x 17 lb/10^6 scf fuel = $\frac{0.05 \text{ lb CO}}{\text{hr}}$ = 0.006 g/s

2750 scf fuel/hr x 3 lb/10^6 scf fuel = $\frac{0.009 \text{ lb HC}}{\text{hr}}$ = 0.001 g/s

2750 scf fuel/hr x 230 lb/10^6 scf fuel = $\frac{0.633 \text{ lb } NO_2}{\text{hr}}$ = 0.008 g/s

Total Incinerator Emissions (natural gas combustion + waste combustion)

PM = 0.34 + 0.005 = 0.345 g/s

SO_2 = 0.12 + 0.001 = 1.121 g/s

CO = 0.48 + 0.006 = 0.486 g/s

HC = 0.15 + 0.001 = 0.151 g/s

NO_2 = 0.15 + 0.08 = 0.23 g/s

PROJECT NAME - Kuparuk River Unit

Incinerator Exit Velocity Calculation (CPF-1)

765 lb/hr combined waste incinerator-assumed 30% moisture

Dry combustibles = 765 lb/hr x .7 = 535.5 lb/hr

Moisture total = 765 lb/hr x .3 = $\frac{229.5 \text{ lb/hr}}{765 \text{ lb/hr}}$

Volume of Combustion Products in Primary Chamber

Volume through flame port with 200% x's air

267.72 scf/lb AP-40, page 446

Fuel 2750 scf fuel/hr x 14.35 scf flue gas/scf fuel gas = $3.95 \times 10^4 \frac{\text{scf flue gas}}{\text{hr}}$

Garbage 535.5 lb/hr x 267.7 scf/lb = 1.43×10^5 scf/hr

Moisture 229.5 lb/hr x $\frac{390.6 \text{ scf/mole}}{18 \text{ lb/mole}}$ = 4.98×10^3 scf/hr

Total volume of combustion products through primary chamber = 1.87×10^5 scf/hr

Volume Through Secondary Chamber

Assume 50% theoretical air added. 85.12 scf/lb AP-40, page 446

535.5 lb/hr x 85.12 scf/lb x 0.5 = 22,791 scf/hr

Total volume of combustion products

Volume through primary chamber	= 1.87×10^5 scf/hr
Volume through secondary chamber	= 22,791 scf/hr
Total volume of combustion products	= 2.10×10^5 scf/hr

Incinerators (continued)

Q = Volume of Waste Combustion Products + Volume of Fuel Combustion Products

$$Q = 2.1 \times 10^5 \frac{scf}{hr} \times \frac{m^3}{35.31\ ft^3} \times \frac{hr}{3600s}$$

$$Q = 1.65\ m^3/s$$

$$A = \frac{\pi D^2}{4} \qquad D = 0.76\ m$$

$$A = \frac{\pi (0.76\ m)^2}{4}$$

$$A = 0.45\ m^2$$

$$\text{Velocity} = \frac{(Q)\ (T_2)}{(A)\ (T_1)}$$

$$V = \frac{(1.65\ m^3/s)(1255°K)}{(0.45\ m^2)(298.2°K)}$$

$$V = 15.4\ m/s$$

APPENDIX C

METEOROLOGICAL DATA PROCESSING

DATA SOURCES

Three sources of meteorological data were used to develop the annual Joint Frequency Function (JFF) and the modified short-term PREP data files for the modeling effort:

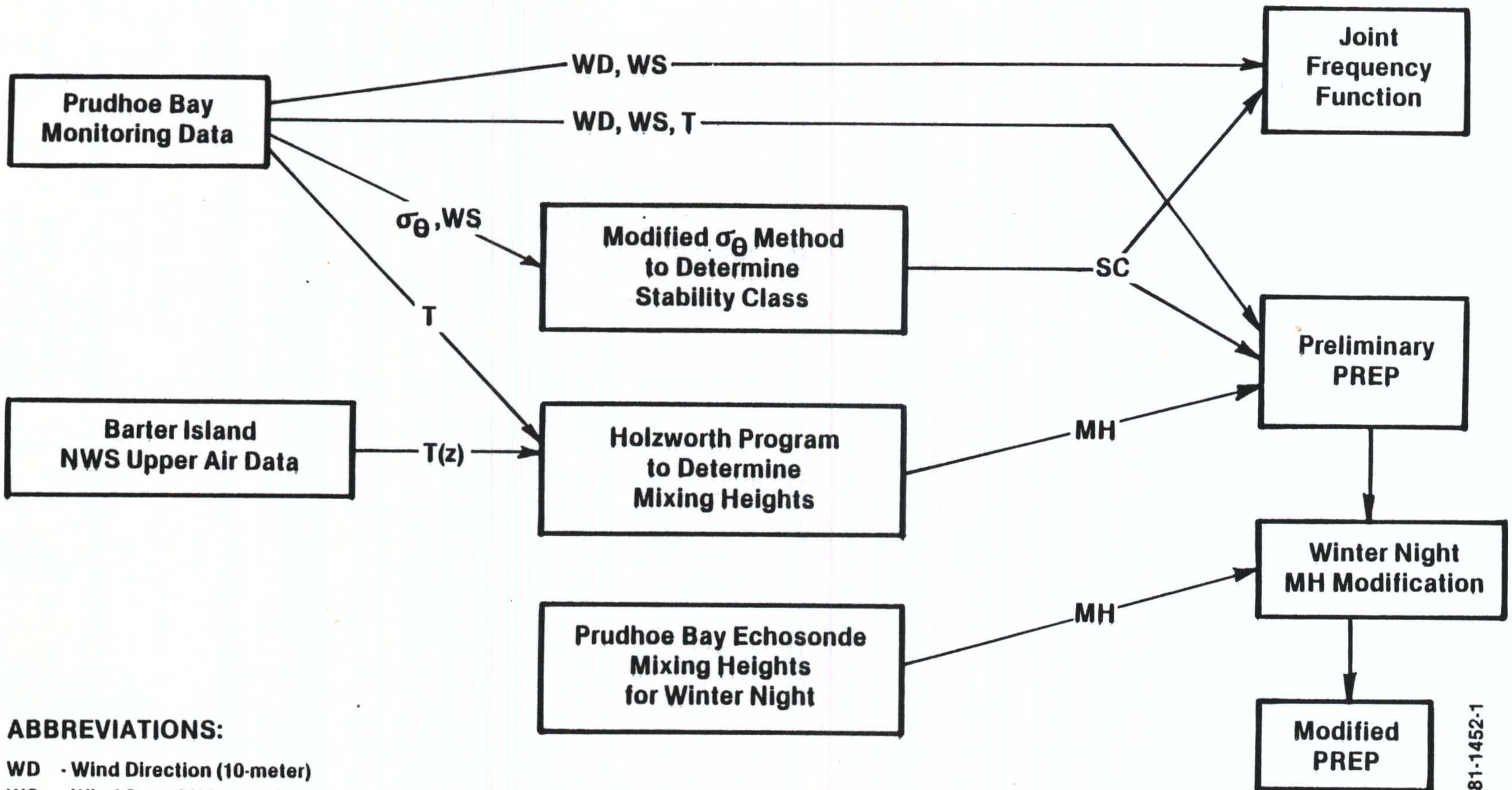
- Prudhoe Bay meteorological monitoring data,
- Barter Island National Weather Service (NWS) upper air data, and
- Prudhoe Bay acoustic sounder mixing heights for the winter night period.

Data for the period from April 1, 1979 through March 31, 1980 were processed according to the flow diagram shown in Figure C-1. The Prudhoe Bay monitoring data that were processed include 10-meter wind direction, wind speed, and temperature measurements from the Well Pad A site (Trailer 041) and 60-meter wind direction standard deviation measurements (σ_θ) from the Sohio Tower site (Site 039).

STABILITY CLASS DETERMINATION

Hourly stability class estimates were made according to the modified σ_θ method recommended in the Guideline on Air Quality Models, Proposed Revisions (EPA OAQPS Guideline Series, October 1980), with two exceptions:

- the σ_θ measurements from 60 meters were used, with a modification of the stability class limits to apply to 60 meters, since 10 meter σ_θ measurements were not available, and



ABBREVIATIONS:

WD - Wind Direction (10-meter)
WS - Wind Speed (10-meter)
T - Temperature (10-meter)
SC - Stability Class
MH - Mixing Height
T(z) - Vertical Temperature Profile
σ_θ - Wind Direction Standard Deviation (60-meter)
NWS - National Weather Service

1-81-1452-1

Figure C-1. Flow Diagram for Meteorological Data Processing.

- E and F stability class estimates that occurred when 10-meter wind speeds greater than 11 knots were changed to D stability.

The formula given by Sedefian and Bennett in "A Comparison of Turbulence Classification Schemes" (Atmospheric Environment, Vol. 14, pp. 741-750, 1980) was used to adjust the σ_θ stability class ranges, as follows:

$$\sigma_\theta(60\ \text{m}) = \sigma_\theta(10\ \text{m})\ (60/10)^{P_\theta}$$

$$= \sigma_\theta(10\ \text{m})\ 6^{P_\theta}$$

$$\begin{aligned} \text{where } P_\theta &= -0.06 \text{ for A stability} \\ &= -0.15 \text{ for B stability} \\ &= -0.17 \text{ for C stability} \\ &= -0.23 \text{ for D stability} \\ &= -0.38 \text{ for E stability} \\ &= -0.53 \text{ for F stability} \end{aligned}$$

The σ_θ ranges for 60 meters were also modified to account for the surface roughness as recommended by the modeling guidelines. A roughness parameter of $Z_o = 0.27$ cm was used. This roughness value was determined from 40 and 60 meter wind speed observations at the SOHIO tower, using the logarithmic profile equation. Accordingly, the multiplying factor for adjusting the σ_θ ranges for surface roughness is

$$(Z_o/15\ \text{cm})^{0.2} = 0.45$$

Following this procedure, a new set of σ_θ stability class ranges was generated and used for the Kuparuk Oil Field application:

Stability Class	Adjusted σ_θ Ranges for 60 Meters
A	$9.1° < \sigma_\theta$
B	$6.0° < \sigma_\theta \leq 9.1°$
C	$4.2° < \sigma_\theta \leq 6.0°$
D	$2.2° < \sigma_\theta \leq 4.1°$
E	$0.9° < \sigma_\theta \leq 2.2°$
F	$\sigma_\theta \leq 0.9°$

For nighttime conditions (one hour prior to sunset to one hour after sunrise) adjustments to the stability class estimates were made according to the new modeling guidelines, as follow:

If the nighttime σ_θ stability class was	And if the 10m wind speed, u, was m/s	mi/hr	Then the stability class was changed to
A	$u<2.9$	$u<6.4$	F
	$2.9\leq u<3.6$	$6.4\leq u<7.9$	E
	$3.6\leq u$	$7.9\leq u$	D
B	$u<2.4$	$u<5.3$	F
	$2.4\leq u<3.0$	$5.3\leq u<6.6$	F
	$3.0\leq u$	$6.6\leq u$	D
C	$u<2.4$	$u<5.3$	E
	$2.4\leq u$	$5.3\leq u$	D
D	wind speed not considered		D
E	wind speed not considered		E
F	wind speed not considered		F

MIXING HEIGHT DETERMINATION

The Holzworth program from the National Climatic Center was used to compute twice-daily mixing heights based on the vertical temperature profiles from Barter Island in conjunction with 10-meter temperatures monitored at Prudhoe Bay. These twice daily mixing heights were input to the PREP preprocessor program to calculate hourly mixing heights for the one-year period. PREP was not designed to handle situations in which the meteorological data are collected at a monitoring site above the Acrtic Circle. Therefore, PREP was modified to handle the impact of the circumpolar sun on processing meteorological data. These modifications are identical to those discussed in the Unit Owners' Waterflood Application.

Hourly mixing heights produced by the modified PREP program were used for the entire period except for October 2, 1979 through February 2, 1980 when the maximum daily sun elevation above the horizon was less than about 10 degrees. The PREP determination of mixing heights is not applicable to the winter nighttime conditions that occur at the Kuparuk Oil Field because it assumes that unstable conditions occur each day due to solar heating. For the winter nighttime period, mixing height measurements made by an acoustic sounder at Prudhoe Bay were used. Only mixing heights identified with a capping elevated inversion were used in this case. For times during the winter period where a capping inversion was not present, the mixing height was considered to be undefined and an arbitrary, large volume of 5,000 meters was used.

The annual mixing height for long-term modeling was determined by averaging the Holzworth determined afternoon mixing heights. An annual average value of 300 meters was calculated.

APPENDIX D

DISPERSION MODELS

ISC

The Industrial Source Complex (ISC) Gaussian dispersion model (Bowers et al, 1979) is a set of two computer programs that can be used to assess the air quality impact of emissions from the wide variety of sources associated with an industrial source complex. The short-term version of ISC is ISCST and is used to predict short-term ambient concentrations. The long-term version of ISC is ISCLT and is used to predict annual or seasonal average ambient concentrations. The ISC model is designed for use with non-reactive pollutants. ISC is a multiple source model capable of predicting the interactive impacts of groups of sources under either rural or urban conditions and in flat or gently rolling terrain. Sources can be either point sources, volume sources, or area sources.

Briggs' plume rise formulas (Briggs, 1971, 1975) are incorporated into ISC and allow for the computation of distance-dependent and final plume rise for both buoyancy and momentum dominated plumes. In addition, ISC accounts for the effects of stack tip aerodynamic downwash and the effects of aerodynamic wakes and eddies formed by buildings and other structures on plume dispersion (Huber and Snyder, 1976) (Huber, 1977).

The ISC dispersion model is designed to calculate the effects of gravitational setting and dry deposition for plumes containing particulate matter and dry deposition for plumes containing gaseous pollutants. Alternately, the ISC model can calculate total dry deposition in lieu of ambient concentrations. A wind-profile exponent law is used to adjust the observed wind speed from the measurement height to the physical emission height for plume rise and concentration calculations. The Pasquill-Gifford curves (Turner, 1970) are used to calculate lateral (σ_y) and vertical (σ_z) plume spread.

The ISCST model uses sequential hourly inputs of ambient temperature, wind speed, wind direction, stability class, and mixing height to compute concentration or deposition values for averaging periods from 1 to 24 hours. If used with a season or year of sequential hourly meteorological data, ISCST will calculate seasonal or annual concentrations or depositions.

The ISCLT model uses a seasonal or annual statistical summary of meteorological information in the form of a joint frequency distribution of wind speed, wind direction, and stability class as meteorological input. Both seasonal and annual concentration or deposition calculations can be made with ISCLT.

PTPLU

PTPLU is a short-term Gaussian dispersion model designed to predict maximum hourly concentrations as a function of wind speed and stability for point sources located in areas of flat terrain. PTPLU is an updated version of the PTMAX Gaussian dispersion model (Turner and Busse, 1973).

A separate analysis is made for each individual stack. Input to the program consists of the source emission rate, physical stack height, and stack gas temperature. Also required are the stack gas volume flow or both the stack gas velocity and inside diameter at the top of the stack. Additional inputs to the model include the height at which the meteorological data is valid and the power law exponents used to adjust the wind speed to that expected at the physical stack height.

PTPLU determines, for each wind speed and stability class, either the final or distance-dependent plume rise using methods suggested by Briggs (Briggs, 1971, 1975). This plume rise is added to the physical stack height to determine the effective height of emissions. The effective height is used to determine both the maximum concentration and the distance to maximum concentration. The plume rise calculated by PTPLU can take into account stack tip downwash, buoyancy induced dispersion, and the effects of both buoyancy and momentum on plume rise. The Pasquill-Gifford horizontal and vertical dispersion coefficients as reported by Turner (Turner, 1970) are incorporated into the model.

REFERENCES FOR APPENDIX D

Bowers, J. F., J. R. Bjorklund, and C. S. Cheney, Industrial Source Complex (ISC) Dispersion Model User's Guide Vol. 1 and 2. EPA Report No. EPA-450/4-79-030, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, 1979.

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Huber, A. H. and W. H. Snyder, Building wake effects on short stack effluents. Preprint Volume for the Third Symposium on Atmospheric Diffusion and Air Quality, American Meteorological Society, Boston, Massachusetts, 1977.

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APPENDIX E

METEOROLOGICAL DATA USED IN DISPERSION MODELING

TABLE E-1

WORST-CASE 24-HOUR METEOROLOGICAL CONDITIONS FOR TSP (DAY 277)

Hour	Wind Direction (Degrees)	Wind Speed (MPS)	Mixing Height (Meters)	Temperature (Deg. K)	Stability Category
1	83.0	19.3	512.0	272.0	D
2	82.0	19.7	512.0	272.0	D
3	81.0	20.7	512.0	272.0	D
4	78.0	21.0	512.0	272.0	D
5	80.0	21.3	512.0	272.0	D
6	81.0	22.3	512.0	272.0	D
7	81.0	22.1	512.0	271.0	D
8	82.0	22.4	512.0	271.0	D
9	82.0	21.3	512.0	271.0	D
10	82.0	20.2	512.0	271.0	D
11	81.0	21.4	512.0	271.0	D
12	80.0	21.0	512.0	271.0	D
13	84.0	20.5	512.0	271.0	D
14	80.0	20.3	512.0	271.0	D
15	78.0	19.9	512.0	272.0	C
16	81.0	19.4	512.0	270.0	D
17	79.0	19.6	512.0	271.0	D
18	79.0	19.3	512.0	270.0	D
19	78.0	18.9	512.0	271.0	D
20	80.0	18.0	512.0	271.0	D
21	80.0	17.8	512.0	271.0	D
22	85.0	16.3	512.0	270.0	D
23	87.0	16.2	512.0	270.0	D
24	80.0	16.2	512.0	270.0	D

TABLE E-2

ANN RELATIVE FREQUENCY DISTRIBUTION STATION =PRUDHOE BAY(1979-1980)

DIRECTION	SPEED(KTS) 0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	GREATER THAN 21	TOTAL
N	.002231	.005988	.002583	.000352	.000000	.000000	.011154
NNE	.001174	.005753	.001996	.000000	.000000	.000000	.008923
NE	.001292	.007514	.003053	.000235	.000000	.000000	.012093
ENE	.000704	.003640	.002583	.000352	.000117	.000000	.007397
E	.000587	.003405	.002348	.000587	.000352	.000000	.007280
ESE	.001174	.001292	.001409	.000352	.000000	.000000	.004227
SE	.000470	.002231	.001879	.000000	.000000	.000000	.004579
SSE	.000235	.001644	.000822	.000000	.000000	.000000	.002700
S	.000939	.001526	.000587	.000352	.000000	.000000	.003405
SSW	.000822	.000939	.001174	.000235	.000000	.000000	.003170
SW	.000587	.003053	.001409	.000470	.000000	.000000	.005518
WSW	.000235	.001996	.001409	.000704	.000117	.000000	.004462
W	.000704	.001761	.001057	.001174	.000117	.000000	.004814
WNW	.000704	.002583	.001174	.000352	.000000	.000000	.004814
NW	.000939	.002583	.001761	.000470	.000000	.000000	.005753
NNW	.001526	.003737	.002466	.000352	.000000	.000000	.008101
TOTAL	.014324	.049665	.027709	.005988	.000704	.000000	

RELATIVE FREQUENCY OF OCCURRENCE OF A STABILITY = .098391
RELATIVE FREQUENCY OF CALMS DISTRIBUTED ABOVE WITH A STABILITY = .000000

E-3

TABLE E-2. (CONTINUED)

ANN RELATIVE FREQUENCY DISTRIBUTION STATION =PRUDHOE BAY(1979-1980)

DIRECTION	SPEED(KTS) 0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	GREATER THAN 21	TOTAL
N	.000000	.000939	.001409	.000235	.000000	.000000	.002583
NNE	.000000	.000939	.002231	.000117	.000000	.000000	.003288
NE	.000235	.003288	.006458	.000704	.000000	.000000	.010685
ENE	.000235	.002700	.004814	.002818	.000117	.000117	.010802
E	.000235	.001879	.002583	.001526	.000117	.000470	.006810
ESE	.000117	.001292	.002935	.001292	.000000	.000117	.005753
SE	.000000	.000822	.000352	.000235	.000000	.000000	.001409
SSE	.000235	.000117	.000235	.000000	.000000	.000000	.000587
S	.000117	.000352	.000117	.000000	.000000	.000000	.000587
SSW	.000000	.000352	.001292	.000470	.000000	.000000	.002113
SW	.000117	.000704	.000939	.000235	.000117	.000000	.002113
WSW	.000235	.001057	.001174	.001057	.000235	.000117	.003875
W	.000117	.000822	.001879	.001409	.000117	.000000	.004344
WNW	.000000	.000704	.001879	.001761	.000000	.000000	.004344
NW	.000117	.000235	.000939	.000470	.000000	.000000	.001761
NNW	.000000	.000352	.000822	.000587	.000000	.000000	.001761
TOTAL	.001761	.016555	.030058	.012915	.000704	.000822	

RELATIVE FREQUENCY OF OCCURRENCE OF B STABILITY = .062815
RELATIVE FREQUENCY OF CALMS DISTRIBUTED ABOVE WITH B STABILITY = .000000

TABLE E-2. (CONTINUED)

ANN RELATIVE FREQUENCY DISTRIBUTION STATION =PRUDHOE BAY(1979-1980)

IDI
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IDI
IAA

DIRECTION	SPEED(KTS) 0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	GREATER THAN 21	TOTAL
N	.000000	.000470	.000704	.000470	.000000	.000000	.001644
NNE	.000235	.000235	.001174	.000704	.000000	.000000	.002348
NE	.000117	.001879	.006340	.001996	.000117	.000000	.010450
ENE	.000235	.001057	.007045	.008454	.001996	.001879	.020665
E	.000117	.002231	.006223	.007162	.002700	.002113	.020547
ESE	.000117	.000822	.002466	.002231	.000235	.000000	.005871
SE	.000000	.000352	.002113	.000000	.000000	.000000	.002466
SSE	.000000	.000235	.000117	.000000	.000000	.000000	.000352
S	.000117	.000235	.000117	.000117	.000000	.000000	.000587
SSW	.000235	.000000	.000822	.000235	.000000	.000000	.001292
SW	.000000	.001292	.000822	.001526	.000000	.000000	.003640
WSW	.000000	.001057	.001526	.001996	.000235	.000235	.005049
W	.000000	.000587	.001996	.002700	.000704	.000352	.006340
WNW	.000000	.000117	.001409	.002466	.000822	.000117	.004931
NW	.000000	.000117	.000352	.000352	.000000	.000000	.000822
NNW	.000000	.000352	.000000	.000235	.000000	.000000	.000587
TOTAL	.001174	.011037	.033228	.030645	.006810	.004696	

RELATIVE FREQUENCY OF OCCURRENCE OF C STABILITY = .087590
RELATIVE FREQUENCY OF CALMS DISTRIBUTED ABOVE WITH C STABILITY = .000000

TABLE E-2. (CONTINUED)

ANN RELATIVE FREQUENCY DISTRIBUTION STATION =PRUDHOE BAY(1979-1980)

DIRECTION	SPEED(KTS) 0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	GREATER THAN 21	TOTAL
N	.000715	.001644	.003757	.000704	.000000	.000000	.006820
NNE	.001068	.001526	.003288	.003288	.000117	.000000	.009287
NE	.001445	.006692	.015616	.019608	.003522	.001057	.047940
ENE	.000961	.003875	.018786	.052366	.037807	.023600	.137393
E	.001793	.005518	.018669	.046965	.033110	.042151	.148206
ESE	.000435	.003053	.009745	.009510	.004814	.000822	.028429
SE	.000476	.001057	.002818	.001292	.000000	.000000	.005643
SSE	.000355	.000352	.001761	.001644	.000000	.000000	.004113
S	.000121	.000587	.003170	.000704	.000000	.000000	.004582
SSW	.000126	.001761	.010685	.006810	.000000	.000000	.019381
SW	.000491	.004462	.018551	.022191	.005753	.002466	.053914
WSW	.000252	.003757	.017142	.033697	.012446	.011859	.079153
W	.000374	.004696	.018199	.014324	.005636	.007280	.050509
WNW	.000249	.002935	.006575	.004579	.001057	.000587	.015982
NW	.000121	.000704	.003522	.001174	.000000	.000000	.005522
NNW	.000361	.001526	.003405	.000117	.000000	.000000	.005409
TOTAL	.009333	.044147	.155608	.218974	.104262	.089820	

RELATIVE FREQUENCY OF OCCURRENCE OF D STABILITY = .622285
RELATIVE FREQUENCY OF CALMS DISTRIBUTED ABOVE WITH D STABILITY = .000235

TABLE E-2. (CONTINUED)

ANN RELATIVE FREQUENCY DISTRIBUTION STATION =PRUDHOE BAY(1979-1980)

IDIR IDIR IDIRI IAA4	DIRECTION	SPEED(KTS) 0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	GREATER THAN 21	TOTAL
	N	.000359	.000470	.000704	.000000	.000000	.000000	.001533
	NNE	.000601	.001174	.000939	.000000	.000000	.000000	.002715
	NE	.001030	.001761	.006692	.000000	.000000	.000000	.009533
	ENE	.000976	.003522	.006692	.000000	.000000	.000000	.011190
	E	.000374	.002348	.005284	.000000	.000000	.000000	.008006
	ESE	.000604	.001526	.001174	.000000	.000000	.000000	.003305
	SE	.000121	.000352	.000000	.000000	.000000	.000000	.000473
	SSE	.000006	.000704	.000000	.000000	.000000	.000000	.000710
	S	.000240	.000352	.000235	.000000	.000000	.000000	.000827
	SSW	.000364	.001057	.001644	.000000	.000000	.000000	.003064
	SW	.000610	.002231	.006575	.000000	.000000	.000000	.009416
	WSW	.000134	.001879	.006927	.000000	.000000	.000000	.008940
	W	.000372	.002113	.003757	.000000	.000000	.000000	.006243
	WNW	.000715	.000587	.000470	.000000	.000000	.000000	.001772
	NW	.000360	.000587	.000470	.000000	.000000	.000000	.001417
	NNW	.000834	.000704	.000117	.000000	.000000	.000000	.001656
	TOTAL	.007749	.021369	.041681	.000000	.000000	.000000	

RELATIVE FREQUENCY OF OCCURRENCE OF E STABILITY = .070800
RELATIVE FREQUENCY OF CALMS DISTRIBUTED ABOVE WITH E STABILITY = .000235

TABLE E-2. (CONTINUED)

ANN RELATIVE FREQUENCY DISTRIBUTION STATION =PRUDHOE BAY(1979-1980)

	SPEED(KTS)						
DIRECTION	0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	GREATER THAN 21	TOTAL
N	.000587	.001292	.000000	.000000	.000000	.000000	.001879
NNE	.000587	.000939	.000000	.000000	.000000	.000000	.001526
NE	.000587	.001292	.000117	.000000	.000000	.000000	.001996
ENE	.000704	.001292	.000000	.000000	.000000	.000000	.001996
E	.000822	.003405	.000117	.000000	.000000	.000000	.004344
ESE	.001761	.003757	.000000	.000000	.000000	.000000	.005518
SE	.001761	.002348	.000000	.000000	.000000	.000000	.004109
SSE	.001409	.001292	.000000	.000000	.000000	.000000	.002700
S	.001526	.002348	.000000	.000000	.000000	.000000	.003875
SSW	.001526	.002231	.000000	.000000	.000000	.000000	.003757
SW	.001879	.005284	.000117	.000000	.000000	.000000	.007280
WSW	.002231	.002700	.000000	.000000	.000000	.000000	.004931
W	.002231	.002231	.000000	.000000	.000000	.000000	.004462
WNW	.001526	.002113	.000000	.000000	.000000	.000000	.003640
NW	.001057	.002348	.000000	.000000	.000000	.000000	.003405
NNW	.000822	.001879	.000000	.000000	.000000	.000000	.002700
TOTAL	.021017	.036750	.000352	.000000	.000000	.000000	

RELATIVE FREQUENCY OF OCCURRENCE OF F STABILITY = .058119
RELATIVE FREQUENCY OF CALMS DISTRIBUTED ABOVE WITH F STABILITY = .000000

APPENDIX F

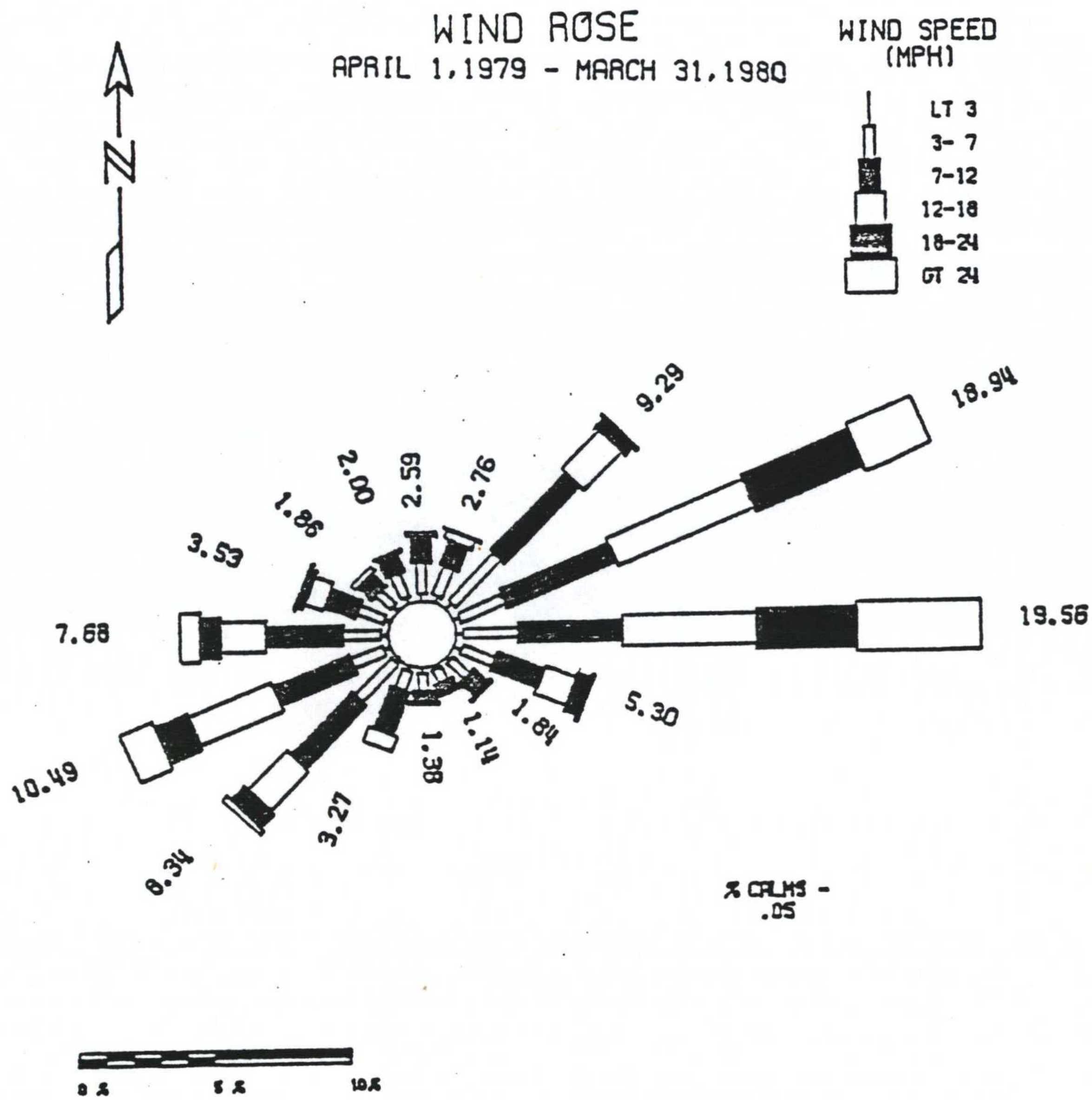
REPRESENTATIVENESS OF THE METEOROLOGICAL DATA

REPRESENTATIVENESS OF THE METEOROLOGICAL DATA

Wind directions and wind speeds used in modeling were those measured at Site 1. A wind rose (joint frequency diagram) for these data is presented in Figure F-1. For comparison purposes, wind roses for Barter Island (1958-1964), the Deadhorse Airport (1976), and Barter Island (1968-1977), are presented in Figures F-2 and F-3. The similarity of wind patterns indicated for these geographically separated locations and different time periods strongly suggests that the Prudhoe Bay Site data are representative of regional climatic conditions.

Stability class distributions for the Prudhoe Bay Monitoring Network, derived as described in Appendix C, are compared with those for Barter Island (1968-1977), which are derived by the Pasquill-Turner method, in Table F-1. When considering the differences in the bases for the stability classifications, it is concluded that the stability data from the Prudhoe Bay Network are reasonable approximations of regional conditions.

Precipitation and temperature data comparisons also indicate that the data measured at the Prudhoe Bay Monitoring Network, and used in the modeling analyses, are representative of the Kuparuk area. Precipitation data recorded during the April, 1979 to March, 1980 period at Point Barrow (3.19 inches) and Barter Island (7.20 inches) indicate a trend of increasing precipitation from west to east along the north coast of Alaska. The data for Prudhoe Bay (Site 2) for this time period (5.34 inches) is in close agreement with this trend. Temperature data recorded at the three 10-meter temperature sensors in the Prudhoe Bay Monitoring Network averaged 12.4°F. The mean annual temperature at Prudhoe Bay Airport during 1971-1973 was 7.9°F. The mean temperature at Point Barrow during the April 1979 to March 1980 period was 3.1°F higher than the climatological normal temperature established from 1941-1979; at Barter Island during the same period, the departure from the 1947-1970 climatological normal temperature was 3.3°F. This may be indicative of regional climatological change. When this difference from long-term mean temperature is considered in conjunction with the difference between 1.8-meter and 10-meter temperatures at Site 2 during the period of simultaneous measurements (more than 1°F), the Prudhoe Bay Monitoring Network data appear to be in close agreement with that expected at the Prudhoe Bay Airport.



PRUDHOE BAY - WELL PAD A

Figure F-1

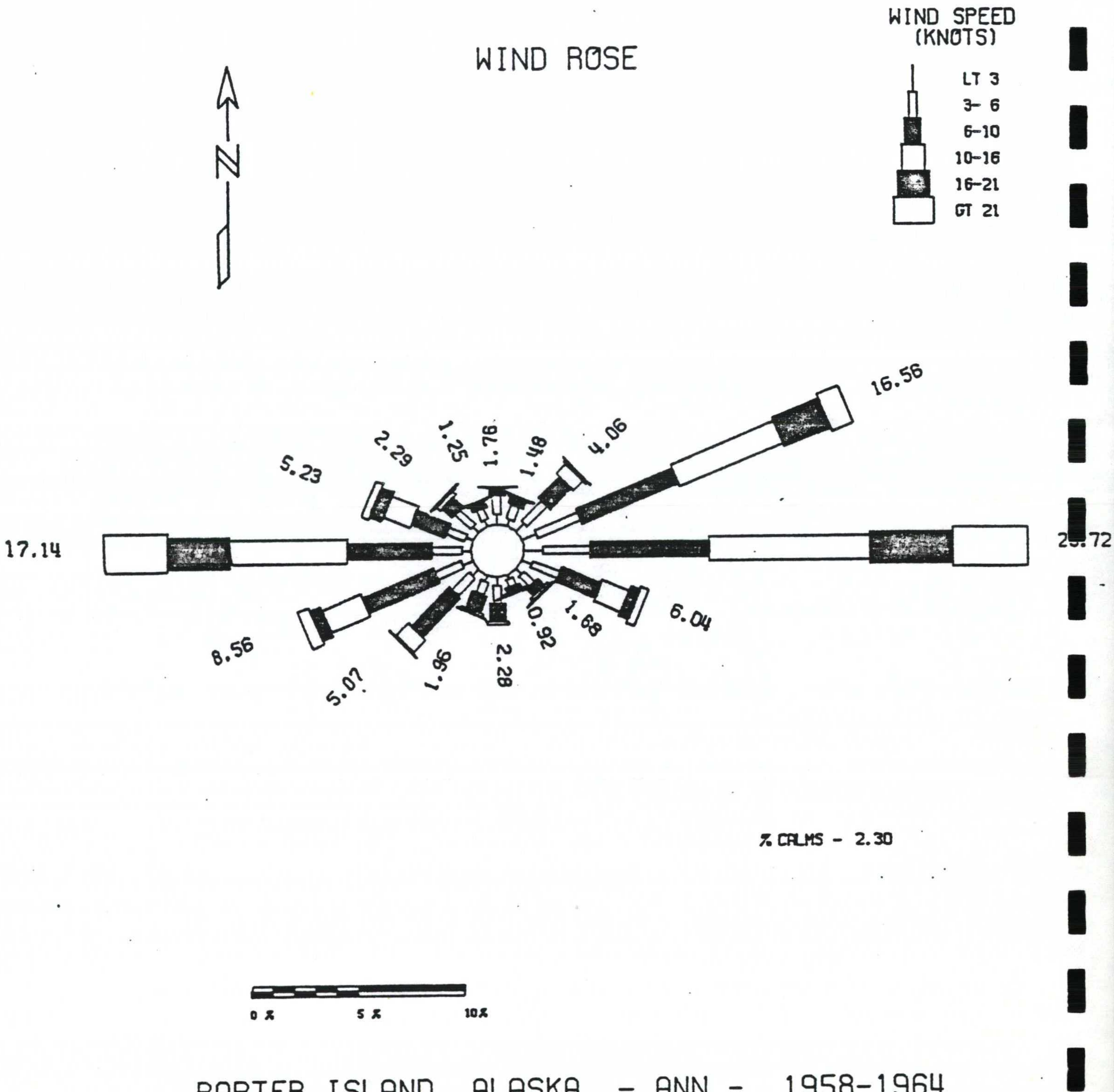
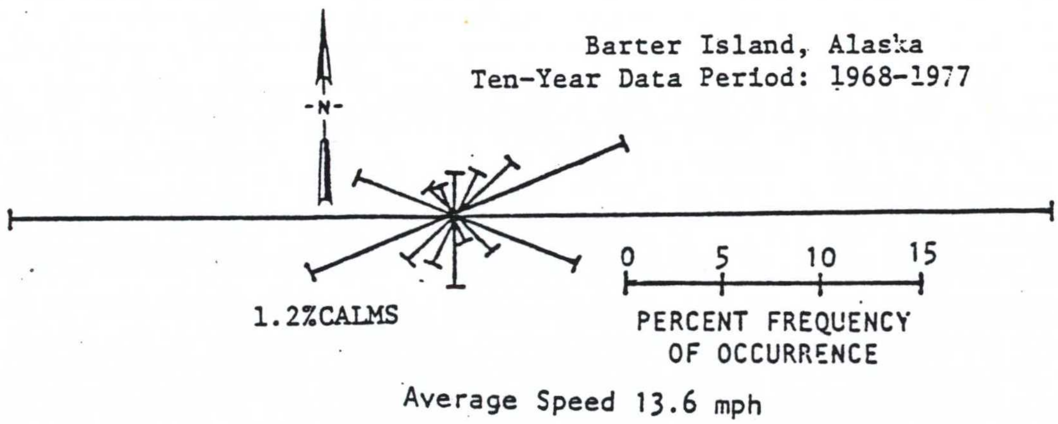

WIND ROSE
WIND SPEED
(KNOTS)
LT 3
3- 6
6-10
10-16
16-21
GT 21
N
16.56
4.06
1.48
1.76
1.25
2.29
5.23
17.14
8.56
5.07
1.96
2.28
0.92
1.68
6.04
% CALMS - 2.30
0 %
5 %
10%
BARTER ISLAND, ALASKA - ANN - 1958-1964

Figure F-2



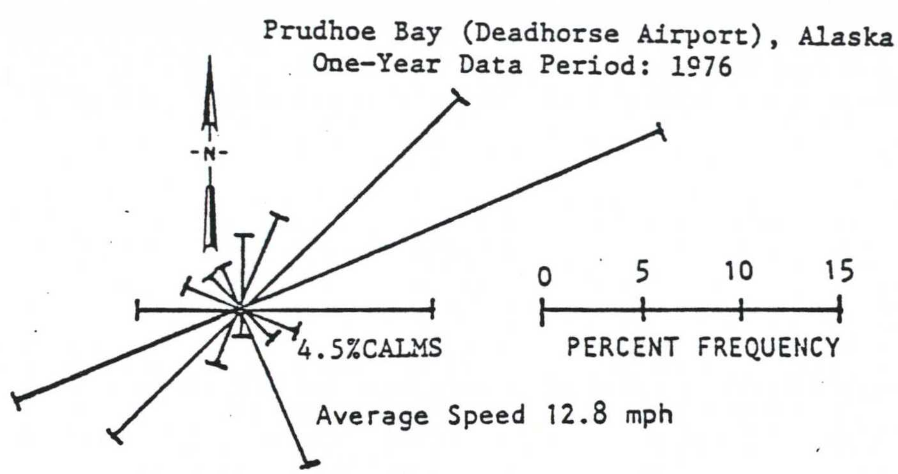


Figure F-3. Annual Wind Roses

TABLE F-1. ANNUAL FREQUENCY DISTRIBUTIONS OF PASQUILL STABILITY CLASSES WITH AVERAGE WIND SPEED BY STABILITY CLASS

		Barter Island (1968-1977)		Prudhoe Bay (1979-1980)	
Stability Class	Definition	Annual Frequency (percent)	Average Wind Speed (mph)	Annual Frequency (percent)	Average Wind Speed (mph)
A	Extremely Unstable	0.00	N/A	9.84	6.1
B	Unstable	0.86	4.7	6.28	8.4
C	Slightly Unstable	4.54	6.3	8.76	11.3
D	Neutral	79.54	13.4	62.23	14.1
E	Slightly Stable	9.36	7.9	7.08	6.7
F	Stable to Extremely Stable	5.70	3.6	5.81	3.8